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A DESTRUCTIVE ROOT DISEASE OF PINEAPPLES AND OTHER PLANTS DUE TO TYLENCHUS BRACHYURUS, N. SP.

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During the past year, considerable study has been devoted to a pineapple-root disease, widespread in its occurrence in the Hawaiian Islands. This disease is characterized by brown lesions, and in more severe cases by the death of many of the branch rootlets and even of some of the main roots. The lesions are caused by a species of Tylenchus, apparently different from any yet described. Often the very common nematode root knot is accompanied by this Tylenchus, and under the combined attack of the two organisms, *Heterodera* (Caconema) *radicicola* and **Tylenchus brachyurus,** n. sp., extreme root destruction sometimes results. This paper deals with the detailed description of the disease, with its distribution in so far as it is known, with experimental inoculations, with the description and identification of the nematode, with its relations to the host tissues, and with observations on the relationship of the nematode to its environment.

DESCRIPTION OF THE DISEASE

Plate XV depicts the characteristic symptoms of the disease. The root lesions which characterize it in the early stages are irregularly elongate argus brown spots. They are somewhat lighter or more dilute in color when very young (*G*), darker and deeper in color as they grow older (*A* and *B*). They show sharp contrasts in surface colors, the edge is sharply delimited from the normal tissues on the side or end, and the surface of the lesion itself is sometimes mottled or striped with darker and lighter browns. The outlines of the ends and sides of a lesion are determined by the outlines of individual dead and discolored epidermal cells. This is shown by Plate XV, *I*. Plate XV, *F*, shows that a single lesion penetrates into the root irregularly, being limited at its greatest depth by the stele. The lesions are not sunken. Their appearance, as illustrated, is very characteristic. They are readily distinguishable from spots and lesions produced by other organisms.

Few or many lesions may appear on a single root, depending upon the degree of infestation of the soil. When many are present they run to-

gether and darken the entire root. Plate XV, *A* and *B*, shows both single lesions and united lesions. The latter result in serious damage. If such regions are at the tip of a root, they stop further growth and the root tip breaks down. Thus large numbers of nematodes are released into the soil to attack such branch roots as may develop. If, as they often are, these heavily infested regions are well up on a young root, the entire cortical region for some distance is destroyed, the vascular system is ultimately

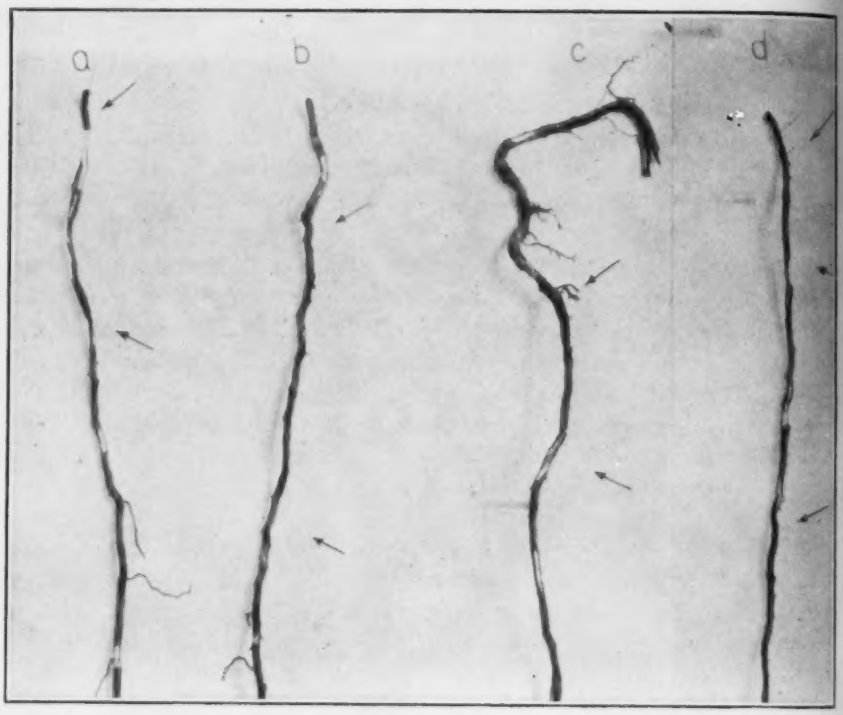

FIG. 1. Well developed pineapple roots, 1½ to 2 feet long, with the cortex completely invaded by Tylenchus in the regions whose limits are indicated by arrows. The root to the left is already dead in this region, which means that the root is doomed. In the other roots the stele is still alive but will probably die shortly. The white areas on the middle portions of the roots are cuts, to show that these regions are normal.

killed, and the entire root below this point, of course, dies. Figure 1 shows a series of roots from a single plant, heavily infested in the upper portions for greater or less distances, the lower portions being relatively free from invasion but doomed, nevertheless. Plate XV, *E*, shows a section of one of the well advanced heavily infested regions, with complete deterioration of the cortex, and evident injury in the stele.

Heavy infestation of the soil results often in the killing of a large number of tender branch rootlets. Plate XV, *A* and *B*, shows the typical appearance of such roots, invaded by the nematodes and still living.

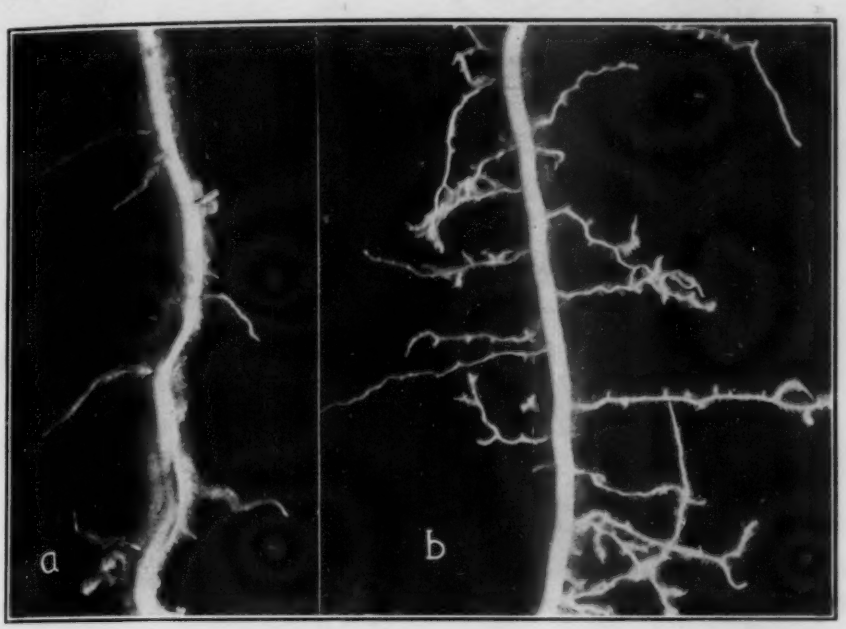

FIG. 2. Differences in branching, and therefore in water-absorbing surface, between a Tylenchus infested (*a*) and a healthy root (*b*). Many of the branch roots in (*a*) have been killed; others have been invaded and checked in growth, and would probably have died.

Figure 2 shows in *a*, a root with branches greatly depleted through invasion by the Tylenchus, and, in *b*, a normal root and branches for comparison. Obviously, the feeding potentialities of the root system may be greatly handicapped by this organism. If the Tylenchus is present in pineapple fields infested by the root-knot nematode, it almost invariably accompanies that nematode in the galls. Its presence can be established macroscopically by cutting or breaking open a firm gall and looking for the brownish color, which is a sure indication. Plate XV, *C* and *D*, shows the typical appearance of a gall beginning to break down because of the heavy Tylenchus infestation. Figure 3 is another root tip suffering from both Heterodera and Tylenchus infestation. As shown by these pictures, the Tylenchus occurs mostly in the outer portions of the root, the Heterodera being established normally deeper in the tissues, with its head end adjacent to the pericycle of the stele. An explanation for the frequent occurrence of the

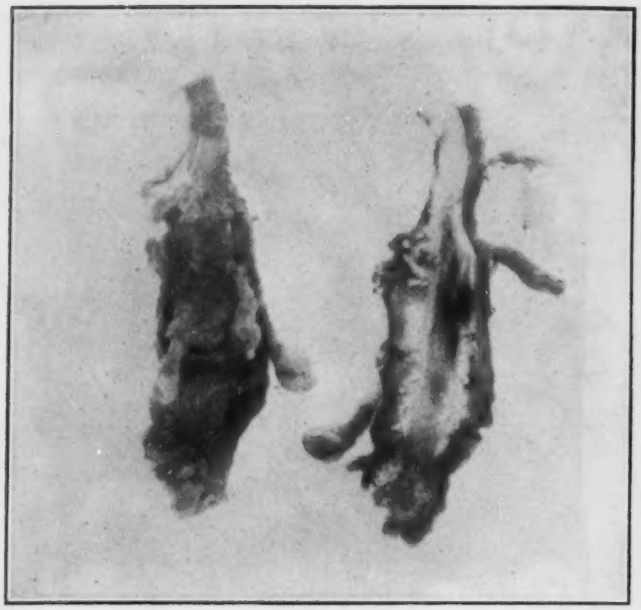

FIG. 3. Heterodera root gall in pineapple, invaded by Tylenchus as well. The picture to the left is a surface view, that to the right a longitudinal section. Such a root, checked in its forward growth by the root knot nematode, becomes an easy prey to the Tylenchus if that organism is moderately abundant in the soil. The cortex and tip of the main root are completely invaded by the Tylenchus, as are also the branch roots. Individuals of the root knot nematode may be seen with their head ends at the border of the stele.

Tylenchus in Heterodera galls is included in the section, "Relation of the nematode to the host tissues."

HOST RANGE, AND SYMPTOMS ON PLANTS OTHER THAN PINEAPPLE

The symptoms on other plants are very similar to those on pineapple. In certain phases of the experimental work during the past year, cowpeas (*Vigna sinensis*) and soybeans (*Glycine hispida*) have been used as indicator crops to show the presence of the root-knot nematode in the soil without disturbing the pineapple plants. Both of these plants have served also as very effective Tylenchus indicators. Infection shows up as brown lesions on the roots and rootlets. Plate XV, *H*, *I*, *J*, and *K*, shows typical symptoms on cowpea roots. *I* is the same lesion as the lower one on *H*, considerably more enlarged. The young roots of these plants are smaller than those of the pineapple, and are structurally more delicate. Consequently, the killing of roots is likely to be more pronounced. Figure 4 shows a

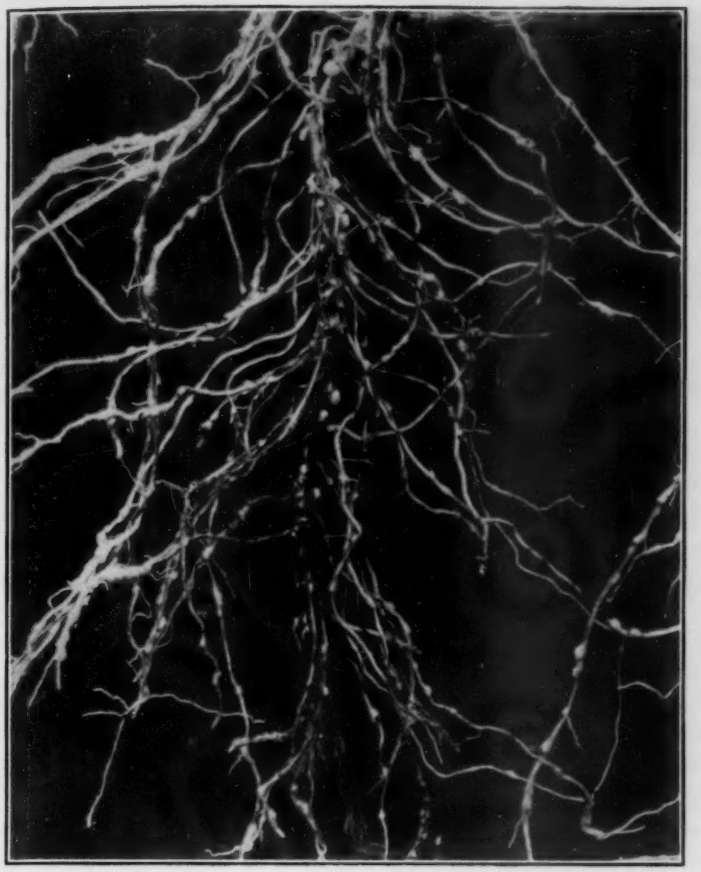

FIG. 4. Heavy Tylenchus infestation in a cowpea root growing under otherwise good conditions. Note the brown striped appearance of the tap root throughout its length. Many of the branch roots likewise show lesions. The tip of the main root has been killed. The tissues were heavily invaded by *Tylenchus brachyurus*.

much branched cowpea root, very heavily infested with Tylenchus. The tip of the main root is wholly decayed, and the remaining discolored portion was found to be heavily populated with Tylenchus in all stages of development.

In tomato, likewise, as used as an indicator crop, similar lesions are to be seen but their scarcity indicates a decided preference of the nematode for other plants. No extreme infestation was found on any weeds, but typical lesions containing the Tylenchus were found on the red-flower "pualele"[1] (*Emilia sonchifolia*) and a few others. Dr. Frederick Muir

[1] Hawaiian for "flying seed."

informs me (personal communication) that he has seen this same form in sugar-cane roots, but never very extensively.

Since the choice of rotation crops will be affected materially by the finding of this nematode, it is expected that a great deal of study will be devoted to its host range.

DISTRIBUTION OF THE DISEASE

The Tylenchus root lesion has been found well distributed over the pineapple plantations in the Hawaiian Islands. The first finding was in the roots of plants from a field on Kauai, in August, 1926. Susbsequent examinations of plants from this same location have shown it to be abundant in that particular field. The gradually accumulating evidence from survey records show it to be present in greater or less seriousness in practically every section of the island of Oahu; and from some parts of the islands, Maui, Molokai and Lanai. Many fields appear to be entirely free from infestation. A complete survey has by no means been made.

Interesting observations have been made from time to time on its occurrence in relation to the root knot nematode. In by far the majority of cases observed both occur together. In many locations the root knot nematode occurs without the Tylenchus. And in some places, root knot has been absent and the Tylenchus has been present.

EXPERIMENTAL

Many inoculation studies were made and it was soon learned that **Tylenchus brachyurus**, n. sp., is capable of bringing about rapid injury to young, actively growing roots of pineapples and other plants. At first a water suspension of adults, larvae, and eggs dissected out from the roots of infested plants from the field, was used as inoculum. This was poured over the young root tips, as they appeared under the glass in our root study boxes (5).[2] In four days primary discoloration was evident. In six days, a lesion such as the smaller ones shown in Plate XV, *G*, was evident. A few days later, lesions were prominent on all inoculated roots. Dissection of such lesions showed that both adults and larvae penetrated the roots. In one instance, eight adults only were placed in a drop of water on a root tip and a lesion developed. A month later, other lesions were evident lower down in the same roots, showing that young had already hatched and the progeny had migrated to growing tips.

Infected roots, cut from plants and placed immediately below developing roots in root-study boxes resulted in heavy infection. Pineapple roots

[2] A complete description of the root-observation boxes used for this type of work has been prepared by Dr. A. L. Dean, Director of the Pineapple Experiment Station of the Association of Hawaiian Pineapple Canners. Figure 5 is a photograph of one of the smaller type of boxes, and shows the excellent availability of roots for inoculations.

FIG. 5. Photograph of root observation box, showing the excellent availability of roots for observation, even with a microscope, and for manipulation. By simply unhooking and swinging back the upper cross-piece, and lifting the glass front, the roots are exposed without undue disturbance.

containing the Tylenchus, placed in tubs of sterilized soil which were later planted to cowpeas, resulted in extremely heavy infestation of this plant. Infested roots of cowpeas placed at the bases of young developing pineapple plants brought about heavy infestation of pineapple roots.

Many inoculations, reisolations of the Tylenchus, and reinoculations were carried through, so there can be no doubt but that the Tylenchus under consideration is the primary cause of the type of root lesions described above in pineapples and other plants.

DESCRIPTION OF THE CAUSAL NEMATODE

Tylenchus brachyurus, n. sp. The nematode causing this root lesion (Fig. 6) is a Tylenchus, very close in general appearance to *T. musicola*

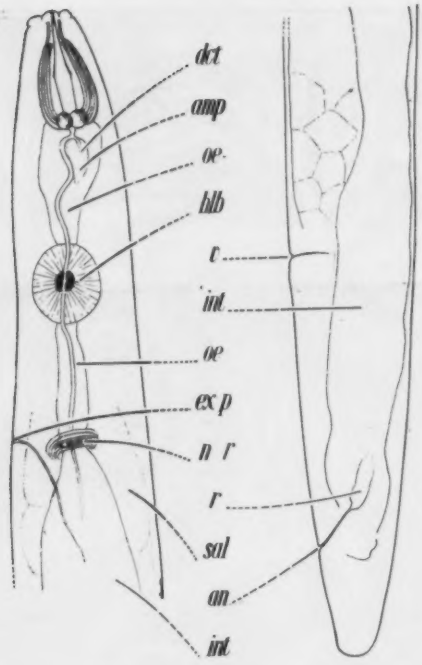

FIG. 6. Drawings of anterior and posterior ends of *T. brachyurus* n. sp. *dct*, outlet of salivary gland; *amp*, ampulla of salivary gland; *oe*, oesophagus; *blb*, median oesophageal bulb; *n r*, nerve ring; *ex p*, excretory pore; *sal*, salivary glands; *int*, intestine; *ov*, ovary; *v*, vulva; *an*, anus; *r*, rectum.

Cobb (3), to *T. pratensis* de Man (*T. penetrans* Cobb) (4, 9), to *T. coffeae* Zimmerman (10), and to *T. sacchari* Soltwedel (10). Contrary to the case with these species, however, only females have been found. Thousands of specimens have been examined in the search for males. The specimens studied were taken from lesions in all stages of development, and from surrounding soil as well. A search was made throughout the roots and soil of cultures resulting from inoculations made on growing roots in sterilized soil, in which many generations developed. If males occur they are exceedingly rare and not essential to reproduction.

Diagnosis: **Tylenchus brachyurus**, n. sp. A Tylenchus, close to *T. musicola* Cobb; differing from it by (1) thicker body throughout (thickness 23.2 μ); (2) consistently shorter proportional distance between the vulva and the terminus (14 per cent compared with 19 per cent) and shorter tail length (4 per cent compared with 7 per cent); (3) the noncuticularized, nonrefractive vulva and vagina wall; (4) absence of irregular extension at end of tail; (5) consistently larger eggs (eggs 80 x 38 μ); (6) absence of males. Measurements of adult female, average of eight specimens, are

included in the following graphic formula. Found principally in pineapple roots in the Hawaiian Islands.[3]

3.3 13.3 15.0 $^{42.5}$86.0 96.1

0.567 mm.

3.2 4.0 4.1 3.8 2.4

The average of measurements of eight eggs is 0.080 mm. x 0.038 mm.

The outstanding differences between this species and *Tylenchus pratensis* are (1) longer and more massive spear in **T. brachyurus**, n. sp. (about 18 per cent greater), (2) about 33 per cent shorter proportional distance between the vulva and the terminus, giving the nematode its distinctly characteristic "short tailed" appearance, (3) the consistently larger eggs, and (4) the lack of males.

Compared to *T. coffeae* Zimm. and *T. sacchari* Soltw., the spear in our Tylenchus is about 20 per cent larger than in the one and 50 per cent larger than in the other; the body length and width are approximately the same in all; the tail is about the same as in *T. coffeae*, much shorter than in *sacchari;* the relative distance (in percentage of body length) from head to vulva is much greater, being 86 per cent in this Tylenchus, and in *T. coffeae* and *T. sacchari*, 80 and 81.2 per cent respectively. Besides these, other differences become manifest after closer study. Zimmerman pictures the ovary (10, figure 7) as extending forward to the front end of the intestine, which would make its length 75 per cent of the body length; in ours no specimen has been seen with an ovary length of more than 60 per cent, the average being considerably less than 50 per cent. The eggs of our species are larger than those of either of the others, as shown by the following comparison:

T. coffeae, 54 μ x 25 μ, *T. sacchari*, 100 μ x 25 μ, **Tylenchus brachyurus**, n. sp., 80 μ x 38 μ.

It is to be seen that **T. brachyurus**, n. sp., eggs are larger in both measurements than *T. coffeae* by about 50 per cent and that they are quite different in shape from those of *T. sacchari*, the latter being long and slender (length to breadth ratio being 4 to 1, while in **T. brachyurus**, n. sp., it is approximately 2½ to 1).

A very simple character by which one species of nematode may frequently be distinguished from another, both being well known to the observer, is the position the nematode assumes when at rest, or when dead,

[3] Differences between this species and *Tylenchus musicola* Cobb are even more clearly established by the detailed description of the latter by Goodey, in a paper received after this manuscript was submitted for publication. (Goodey, T. Observations on *T. musicola* Cobb, 1919, from diseased banana roots. Jour. Helminthology 6: 193–198. 1928.) Attention is called particularly to the differences in the tail region and to the relative position of the vulva.

as viewed under the low powers of a microscope. One Tylenchus encountered frequently in soils from pineapple fields, for instance, takes a very definite spiral position (like a watch spring) when at rest. **Tylenchus brachyurus,** n. sp., straightens itself out completely. In fact, even when active, it rarely assumes the spiral position. It is more apt to assume

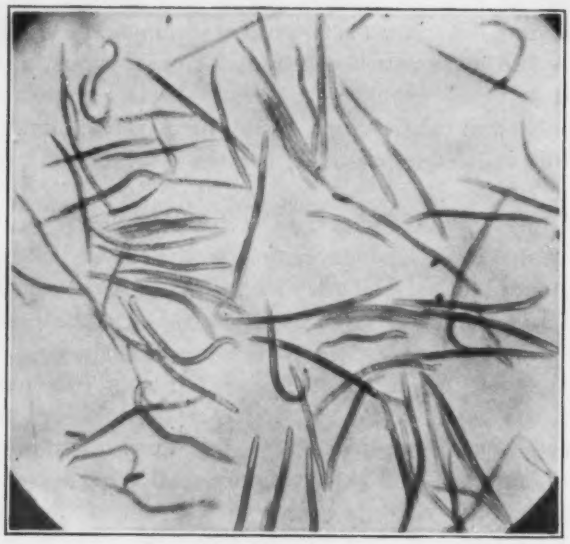

FIG. 7. Miscellaneous assortment of *T. brachyurus* eggs, larvae, and adults. When at rest, this nematode is usually straightened out, or only slightly bowed. When active, it is sluggish in its movements, and bends in the body are usually more or less angular—never spiral. Magnification about 30 diameters.

irregular angles at different points in the body. Figure 7 illustrates a miscellaneous assortment of **T. brachyurus,** n. sp., eggs, larvae, and adults, in normally quiescent and active positions, just as taken from a pineapple-root lesion.

A detailed description follows, including further characteristics, some of which would seem to indicate specific differences from any other known Tylenchus. The nematode would belong to Micoletzky's (7) subgenus Chitinotylenchus. There are six distinct lips. Thickened divisions between the lips are attached to the elongated guiding ring near the front end of the spear. This makes a very distinct cuticularized framework which, including the fore part of the spear, is sloughed off with the final moult, as is the case with *Tylenchus pratensis* and others.

There is no chitinization in the region of the vulva. The "lips" of the vulva protrude only slightly. A distinct rectum slightly anterior to the anus was observed in some specimens.

The lateral fields show four distinct longitudinal striae. Lateral wings, if they occur, are not pronounced. There are distinctly fewer annules in the lateral fields than on the dorsal and ventral fields. The posterior end of the left field and its relation to the tail are shown in figure 8, *a*.

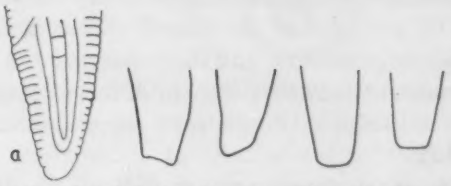

FIG. 8. Drawings of tail ends of *T. brachyurus*. The cuticular rings are shown in *a*; the other four show variations in the outline of the tail, all alike being left lateral views.

The tail is short, varying from 4 per cent to 5 per cent of the length of the body. It varies considerably in outline with different individuals. In figure 8, every drawing shows the left lateral view. There are usually about sixteen rings posterior to the anus, but in some unusually large specimens as many as twenty-two have been counted. There are between three hundred and four hundred rings in the entire body length.

Amphids are present, the sensillae extending back of the spear about half its length. The duct from the anterior salivary gland empties into the lumen of the oesophagus on its dorsal side a short distance back of the spear bulbs. In some specimens, under best conditions for observation, a suggestion of glandular tissue, set off from surrounding parts by its granular appearance, was seen just back of the spear, and extending backward to an undetermined extent. While all details could not be determined, it would appear to correspond with the "ampulla" described by Cobb (2) for *Tylenchus similis*. It is shown in figure 6. Muscles operating the spear are distinct. The fore part of the oesophagus is distinct, as shown by figure 6. It is wider in the anterior half, being about half the body width in this region, then narrows down posteriorly, to a relatively narrow cylindrical tube one-fifth the body width connected with the median oesophagus bulb, with a slight but distinct constriction. The spherical to ellipsoid median oesophageal bulb is typical of the genus. The rear portion of the oesophagus is less distinct, but in some specimens is visible as a somewhat narrow cylindrical tube, widening out at the posterior end, into the intestine, with no constriction. A nerve ring is visible just in front of the beginning of the posterior enlargement. The salivary glands may be seen obscurely, extending longitudinally posterior to the nerve ring. The excretory pore, on the ventral surface, is very distinct and has a

plainly visible long duct leading undoubtedly from a rennette gland somewhere posteriorly, beside the intestine, though its position was not determined. The relative position of the excretory pore with regard to the cardiac region is very irregular, being anterior, opposite, or posterior to it, in different specimens. A single anterior ovary varies in length between 30 per cent and 60 per cent of the length of the nematode, and is not reflexed. As a rule only one egg, and that unsegmented, has been found in the uterus. As many as four in a line, in different stages of development were found in one individual. Single eggs, segmented, have been observed, as have two together.

Some of the internal characters are difficult to determine in living specimens, owing to the abundance of fatty substance. By selection of specimens which appear clear under the dissecting binocular, the interior details can be determined more readily than in specimens not so selected. Excellent material for study of internal details was secured with specimens killed within the host tissues with Zenker's killing fluid, sectioned 6 and 8 μ thick, and stained with phosphotungstic acid haemotoxylin. Since most of the nematodes lie outstretched longitudinally in the root tissues (see next section), it is often possible to secure complete longitudinal sections.

Such sections showed to particularly good advantage the outlines of the oesophagus, including attachment to the intestine; also the nerve ring, and to some extent the glandular tissues. Nuclei were not deeply stained, so other details could be studied the more readily. Interestingly, this stain brought out in deep purple (or lighter, with lighter stained material) the muscle fibrils. These were prominent particularly in the muscles surrounding the spear, and this gave the head region an unusual appearance, partly, too, because the spear itself was rendered all but invisible. The muscle fibrils of the body-wall muscles were made to stand out prominently. These "strands," arranged longitudinally, and parallel and close to the body wall, gave the animal a distinct longitudinally striated appearance probably the "longitudinal muscular bundles" mentioned by Bastian (1, p. 80). In transverse mid-sections of an adult female nematode, ovary, intestine, and lateral chords are distinct, and muscle fibrils appear as black dots in dorsal and ventral body walls.

RELATION OF THE NEMATODE TO THE HOST TISSUES

As a rule, only the parenchyma cells of the cortex of a root are invaded by the nematode. The stele, after it has been differentiated in the region of branching, back of the region of elongation in a root, escapes penetration by the organism, at least for a long time. Consequently, a root may survive and grow for some distance even though the cortex surrounding it

in places may be completely invaded and killed. The organism seems to be limited by lignified cell walls. Thus even a slight degree of hardening of the epidermal cells prevents primary penetration on the part of nematodes from the soil, and also prevents the spread of the lesion itself, superficially. Lesions spread almost entirely subepidermally, after primary penetration of the young root has occurred.

The nematodes are, at best, sluggish in their activities. Fast growing roots will usually grow away from individuals that may have penetrated at or near the growing tip of the root. This accounts for the fact that most of the lesions occur on the sides of a root, with the growing tip apparently untouched. It is only in a case of heavy infestation of the soil or where the root has in some way been retarded in its forward progress that serious invasion takes place in the root tip. This constitutes the principal exception to the rule of invasion of the cortex only; and a serious exception it is for the welfare of the plant. When the nematodes become established in sufficient numbers in the meristematic tissue of the root tip, the root is quickly killed. Plate XV, *B*, shows a root tip thus invaded. It is to be noted too that when a root is thus severely attacked the young branches arising in the region of branching, an inch or two back of the tip, are often attacked and prevented from development. Such branch roots with the discolored portions invaded by nematodes, are shown in Plate XV, *A* and *B*, and in text figure 2, in which in *a*, most of the important lateral "feeding" roots are destroyed; whereas, in *b*, a normal root, they are fully functioning. Cases have been observed in which primary invasion was directly through the root cap.

As was stated before, the stele usually escapes penetration and the root continues to grow in spite of the invasion of the cortex. Initial infections in the upper part of young roots may continue to develop in the cortical cells, however, until the cells are entirely destroyed in the entire circumference of the root, and for several inches of its length. Such heavy infections may eventually reach a stage when, either directly or by means of toxins or secondary organisms, the vessels of the vascular system are killed. This appears to happen rather suddenly, for many roots on a given plant have been observed in different stages of infection, some of them with apparently dead tissues throughout the root in the region of the large lesions described, and all still showed the root tips to be healthy or barely wilted. Such roots rapidly deteriorate and eventually decay. Figure 1 shows such roots, healthy in the lower portions, but completely girdled by Tylenchus lesions in the regions indicated. Much of the death of long well-developed pineapple roots can be attributed to this cause.

Most of the nematodes abandon infested regions, shortly after the tissues have been killed. A great many roots have been examined, in which the

typical symptoms in the cortex indicated that heavy infestation had once been present, but which showed a very small present population. The nematodes, larvae and adults alike, migrate into the soil and seek new young roots. In the pineapple plant, root development is to a certain extent by spurts, depending upon the degree to which conditions favor growth. The new roots, growing down through the soil occupied by a first lot of roots badly damaged by Tylenchus, are often attacked in an early stage, with subsequent killing in the manner described in the previous paragraph.

Excellent low-power observations on the location and arrangement of the nematodes within the host tissues were obtained by a process which I developed as a modification of Arzberger's method of studying mycorrhizal fungi, while working at Madison, Wisconsin, from 1921 to 1923, and which I have modified somewhat since. Steiner has mentioned this method of study of nematodes within roots, or something similar to it (8), and has used it for observations and illustrations (9). My method consists of killing the tissues with hot (approximately 50° C.) Flemming's medium or strong killing fluid, leaving for a half hour or so only, transferring to chrom acetic fixing fluid for 12 to 24 hours, washing, dehydrating, and clearing in clove or some other oil. The osmic acid of Flemming's fluid stains the nematodes without staining the plant tissues, so that in the cleared specimen the nematodes stand out clearly. Figure 10, *a*, is a photograph of such a view of **T. brachyurus**, n. sp., in a pineapple root, and figure 9, b, of those within lesions in a cowpea root. Adults, larvae, and eggs may sometimes be seen in great numbers in the tissues. They usually are to be found at the advancing ends of the lesions rather than in the center, where the tissues have disintegrated. The nematodes work their way through the tissues, feeding as they progress. They are not confined to the intercellular spaces, but break readily through the cell walls. A row of two or three to half a dozen or more eggs, evidently deposited by a single adult female, may often be seen just back of her in the damaged tissues.

Materials for the study of histological and cytological details, in young lesions, were killed with hot (50 to 55° C.) killing fluids of different kinds, washed, dehydrated, and infiltrated with paraffin according to the usual methods. Young lesions, near the tips, could be very satisfactorily processed for sectioning. Older lesions, farther up on the roots, contained so much silicified tissue that they could not be cut without first treating with hydrofluoric acid for ten days or two weeks, prior to dehydration. The histological work reported herein was done by Dr. R. C. Whitman, of the University of Colorado, who is spending his sabbatical leave at the Pineapple Experiment Station.

A careful study of sections 6 and 8 μ thick verifies conclusions from macroscopic examinations that lesions spread within the cortex subepider-

FIG. 9. Photographs of nematodes within roots; *a*, pineapple, and *b*, cowpea. The roots were first killed with a killing fluid containing osmic acid (warm for instantaneous killing), fixed with chrom acetic fluid, washed, dehydrated, and cleared in clove oil. This is an excellent way to demonstrate nematodes in plant tissues.

mally and mostly in a longitudinal direction. The nematodes enter the roots through the epidermal cells, sometimes through root hairs. They force their way through the cells, destroying them as they go. Apparently, they are limited not at all by the cell walls of the cortical parenchyma. As a rule, they at first move along longitudinally in the root in the outer two or three layers of cells. Cross sections almost invariably show clean-cut transverse sections of the nematodes in this region. They then turn inward and move through the tissues either singly or in groups of several, causing quick and complete death of the cells they penetrate and disintegration of the cell contents. A distinct discoloration of the tissues follows quickly after penetration by the nematodes. To what extent secretions play a rôle in the death of the cells is not clear. It is certain, however, that uninjured cells with the nuclei intact have been seen immediately adjoining the body of the nematode. (See Fig. 10, *a* and *b*.) Considerable regions in a root are often killed by nematodes and then are completely abandoned by them. I am not always able to decide with certainty whether certain cells, obviously dead, have been killed by direct invasion, possibly penetration of the spear alone (the walls being apparently intact), or whether they have been killed by toxic secretions from the nematodes, or by some other means. Possibly

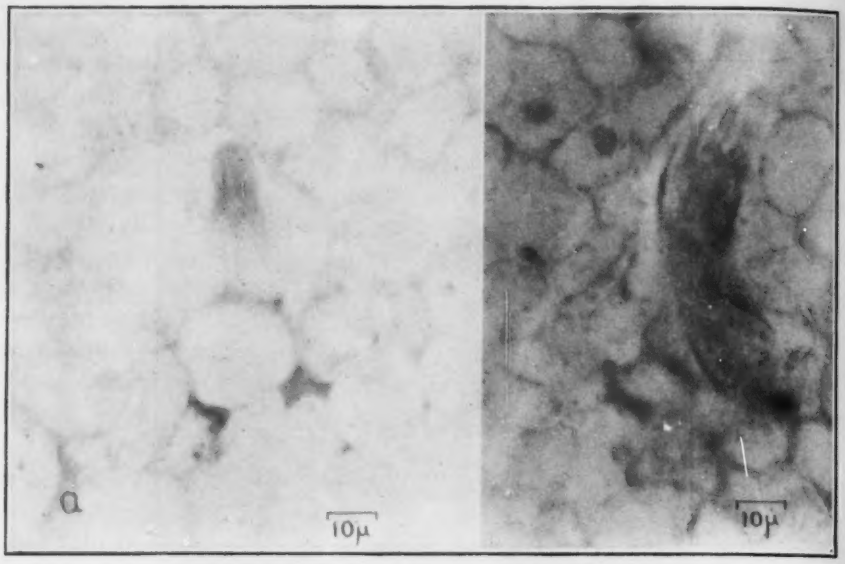

FIG. 10. Photomicrographs showing *T. brachyurus* within the cortical tissues of pineapple roots. Note the uninjured host nuclei in cells immediately adjoining the body of the nematode. In other cells, already traversed by the nematodes, the cells are killed, and cell contents disintegrated.

death of such cells may sometimes be physiological, due to the complete interference with normal nutrition brought about by the killing of a considerable region of adjacent tissue.

The older lesions are frequently accompanied by invasions by secondary organisms. Bacteria have often been seen which had advanced intercellularly to the very limits of invasion by the nematodes. Fungi also have been seen in sections of roots attacked by the Tylenchus, obviously as secondary invaders in nematode invaded tissues; sometimes they appear to have advanced from lesions into otherwise uninjured tissues. A species of Cephalobus, a nematode of doubtful parasitic habits, has been seen within Tylenchus lesions; it is invariably surrounded and preceded by bacteria. In younger lesions, many advancing edges have been studied that appear to be completely sterile in so far as organisms other than the Tylenchus are concerned.

SOME OBSERVATIONS ON ENVIRONMENTAL RELATIONS

Detailed work on environmental relations of **Tylenchus brachyurus**, n. sp., has not been done. However, miscellaneous observations, some of which are significant, have been recorded from time to time. The impres-

sion has been gained, from laboratory observations, that the Tylenchus is more resistant to adverse conditions, particularly to drying, than is Heterodera. Mounts left standing on slides, or suspensions in dishes left to complete dryness are more apt to show recovery to activity of some individuals than is Heterodera. Living specimens can frequently be recovered from field roots that appear to be dry.

Accurate observations were made in conjunction with studies on the drying of soils containing primarily *Heterodera radicicola* (6) but having a heavy Tylenchus population as well. In this test, a large volume of soil was uniformly heavily infested with both Heterodera and Tylenchus by mixing with it the roots of sixty pineapple plants heavily infested with both nematodes. The soil was divided among several large wooden tubs filled to a depth of ten inches. Tubs were subjected to several different conditions, including in one lot, continuous drying with complete stirring once a week, and in another lot the maintenance of the soil under good conditions for growth, in so far as watering was concerned. Four months of complete drying eliminated the last trace of living Heterodera, as evidenced by cowpeas as an indicator crop. The same indicator crop showed, however, that the Tylenchus survived to a surprising degree. Some of the plants showed heavy infestation; in fact, figure 4 is taken from one of the plants of this lot. The Tylenchus was shown to be capable, in an inactive state, of surviving over a considerable period, and of quickly resuming activity and capacity for infecting plant roots on the restoration of favorable conditions. One of the measures recommended for the control of the root-knot nematode, namely continuous dry fallow with frequent stirring of the soil for several months during a dry period, will not, therefore, be effective in eliminating the Tylenchus. An encouraging feature developed, however, in the continuously moist series of tubs. Here it was determined that after four months a very much lower Tylenchus population was left; less than 1 per cent of that in original plantings. The conditions being favorable for the continuous activity of the nematode, in its search for food it depleted its store of reserves, and starved.

Observations on pineapple-field soils, including careful nematode determinations through a series of fallow treatments, have shown definite reduction of Tylenchus as well as of Heterodera (6). On the basis of these various observations, it is certain that the Tylenchus population of pineapple-field soils may be greatly reduced in the inter-crop period by a period of clean fallow during moist weather. Possibly the growing of immune crops during this period will have the same effect. Such procedure can be made to fit very well with the root-knot-nematode reduction program. Field tests are under way to get additional definite information on this point.

SUMMARY

One factor contributing to root failure in pineapples in Hawaii is a root lesion produced by a species of the nematode genus Tylenchus. Lesions on young roots are irregular, longitudinal, argus brown spots, from one to several millimeters long, extending through cortical parenchyma cells but not into the stele. The nematodes multiply and migrate in the cortex, destroying the cells, until finally the root is killed. Branch feeding roots are often greatly reduced in number. The nematodes are sluggish, and lightly infested roots grow away from them and continue to function. When soil infestation is sufficiently heavy so that numbers of nematodes invade root tips, severe injury results and further growth of the root is prevented. Injury to the root tissues appears to be purely mechanical. Histological studies show root cells adjacent to the invading nematode with nuclei intact. Nematode root knot checks forward growth, making conditions ideal for penetration and multiplication of the Tylenchus, which then rapidly breaks down the tissues. Presence of the Tylenchus in a gall is always indicated by a brownish color. The two nematodes together make a destructive combination. Other plants subject to attack are tomato (slightly), soybean, cowpea (very heavily) and many weeds. In contrast with *Heterodera* (*Caconema*) *radicicola* the Tylenchus is resistant to drying. Its numbers are greatly reduced, however, in moist soil fallow, probably by starvation. The nematode is described as **Tylenchus brachyurus**, n. sp.

EXPERIMENT STATION, ASSOCIATION OF
HAWAIIAN PINEAPPLE CANNERS.

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EXPLANATION OF PLATE XV

Tylenchus brachyurus n. sp. in pineapple and cowpea roots.

A to G. Typical lesions in pineapple roots.

A and B. Severe injury in main root and laterals. Root knot symptoms, produced by *Heterodera radicicola*, are evident as well.

C and D. Surface view and longitudinal section, respectively, of a root tip invaded by both the Tylenchus and the Heterodera. The region invaded by the Tylenchus is evidenced by the dark color.

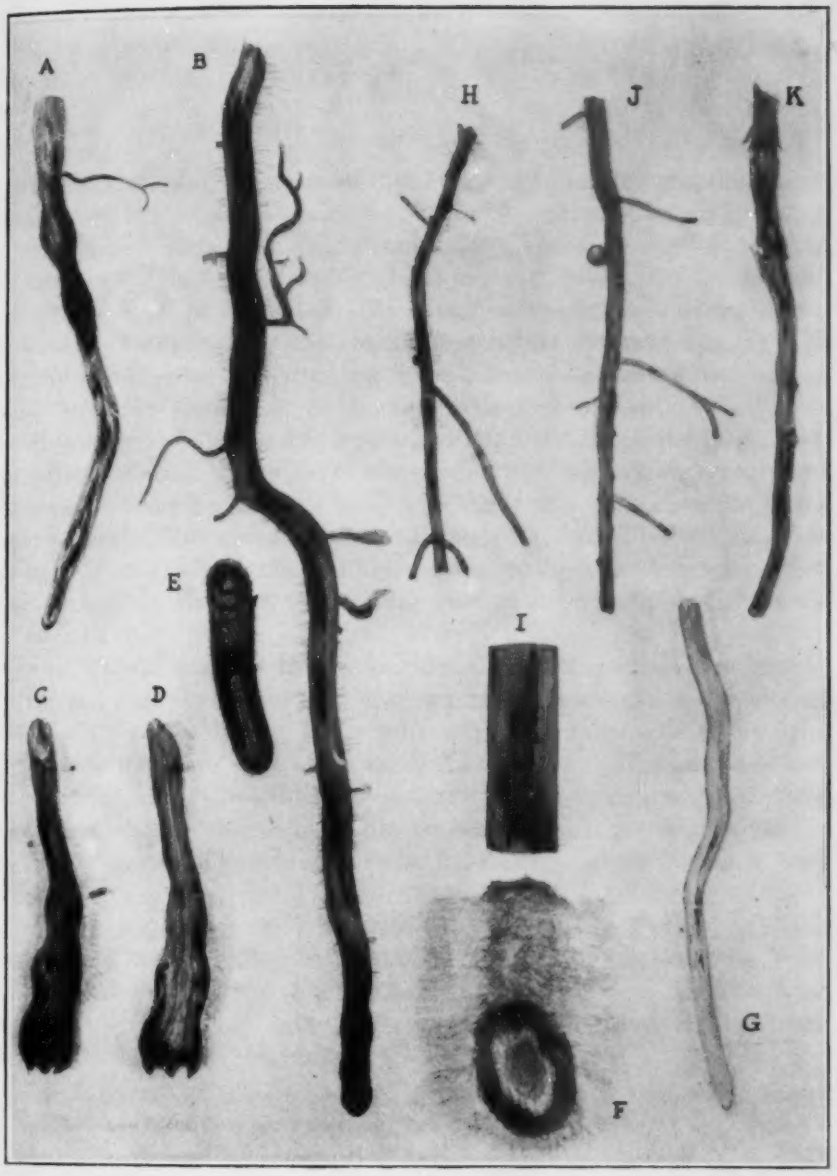
E. A portion of an older root that has been killed by the advance of the Tylenchus within the cortex. Note that the lesion has spread subepidermally until the entire cortex has become brown.

F. A somewhat younger root than that shown under E, the root hairs being still intact. The depth of penetration of a lesion is here evident.

G. Very young lesions on a pineapple root.

H to K. Lesions in a cowpea root. The one in I is the same as the lower one in H, magnified about five diamaters. In K the tissues are beginning to disintegrate, consequent to the invasion of secondary organisms.

The lesions are, in color, very close to the "argus brown" of Ridgeway.


A
B
H
J
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G
F

SULPHUR DUSTING FOR THE PREVENTION OF STEM RUST OF WHEAT[1]

E. B. Lambert and E. C. Stakman

INTRODUCTION

For many years it was assumed that *Puccinia graminis* Pers., the fungus causing stem rust of small grains, could not be controlled either by spraying or dusting. Kellerman (6), Pammel (10), and Galloway (4) applied a number of fungicides to growing plants to ascertain whether the development of rust could be prevented. They used both sprays and dusts, including flowers of sulphur, but the results were not at all encouraging. The dusts were ineffective and spraying large acreages of small grains with a liquid fungicide seemed to be impracticable and probably would have proved to be so. With the development of improved fungicidal dusts, however, attention again was called to the possibility of controlling cereal rusts by dusting. Some preliminary tests[2] were made under the direction of the junior author at University Farm, St. Paul, Minn., in 1923. Sulphur dust was applied to wheat plants, but there appeared to be no beneficial effect, probably because the dust was not fine enough or was not applied at the proper time.

In 1924 there was very little stem rust in the spring wheat area, and no experiments were made. In 1925, however, trials were made on a more adequate scale than in 1923. The results were unusually satisfactory, and experiments therefore were again made in 1926. In the meantime, however, Kightlinger (7) published the results of experiments made at Cornell, and to him must go the credit of having been the first to demonstrate the possibility of controlling cereal rusts by dusting growing plants with sulphur.

In 1926, Kightlinger and Whetzel (8), Bailey and Greaney (1), and Lambert and Stakman (9) published results of dusting trials in New York, Manitoba, Minnesota, and North Dakota, respectively. Since that time Bailey and Greaney (3) and Greaney (5) have published detailed summaries of their subsequent results.

[1] Cooperative investigations between the Minnesota Agricultural Experiment Station and the Office of Cereal Crops and Diseases, Bureau of Plant Industry, U. S. Department of Agriculture. Published with the approval of the Director as Journal Series Paper No. 838, University of Minnesota, University Farm, Minn.

[2] These experiments were made at the suggestion of Prof. H. H. Whetzel, who stated that some of the newer sulphur dusts were so superior to ordinary sulphur that they merited trial as preventives of rust.

After 1926, the Minnesota experiments were continued by W. C. Broadfoot, who made much more extensive experiments in 1927 and 1928. The results of Broadfoot's experiments are being published separately. It seems worth while to publish also the results obtained by the writers in 1925 and 1926, as it is essential to have data for a number of years in order to determine the practical value of dusting.

EXPERIMENTS IN 1925

In 1925, Marquis wheat was dusted with precipitated sulphur at Excelsior, St. Paul, Morris, and Crookston, Minn.; and at Glasston and Tolley, N. D. At Excelsior the experiments were made in a low field. The plots were marked off by stakes in the lowest part of the field, where the likelihood of severe rust attack was greatest. The dust was applied with a hand duster, at a rate of approximately 150 pounds per acre, which was sufficient to cover the plants thoroughly. Treated plots and untreated check plots alternated.

Primary infection by stem rust was first observed in this field on June 17. At the time of first dusting, on June 25, stem-rust spots due to secondary infection were about 1 foot in diameter and occurred, on the average, at 6-foot intervals throughout the field. The wheat plants were flowering on June 25, were in the milk stage on July 2, and were in the hard dough stage on July 17.

The results of the treatments are given in table 1, from which it is evi-

TABLE 1.—*Results of dusting Marquis wheat at Excelsior, Minn., with precipitated sulphur at the rate of 150 pounds per acre, in 1925*

Plot No.	Plots treated (×) on		Stem-rust severity, in the rusted plots, on July 17
	June 25	July 2	
1	×	×	Trace to 5 per cent on peduncles; 40 per cent on sheaths
Check	–	–	80 per cent
2	×	–	80 per cent; plants slightly greener than checks
Check	–	–	80 per cent
3	×	×	Trace to 5 per cent on peduncles; 40 per cent on sheaths
Check	–	–	80 per cent
4	×	×	Trace to 10 per cent on peduncles; 40 per cent on sheaths
Check	–	–	80 per cent
5	×	–	80 per cent; plants slightly greener than checks
Check	–	–	80 per cent
6	–	×	Trace to 10 per cent on peduncles; 40 per cent on sheaths
Check	–	–	80 per cent

dent that one application of dust on July 2, when the wheat plants were in the early-milk stage of development, reduced the rust to a remarkable degree. Two applications, the first on June 25, when the wheat was heading, and the second on July 2, resulted in no greater reduction of rust than did the single application on July 2.

It is clear that one application of dust may control rust, but only if made at the proper time, which, for this field, was about July 2. The first application, made on June 25, seemed to be of little or no value. Apparently it was made too early, and either too much of the dust had been washed off by the time large numbers of rust spores reached the plants, or it was no longer chemically effective.

The field was harvested before material was obtained for determination of yields, but it was perfectly apparent, even on casual observation, that the bundles of dusted wheat were far heavier than those of the non-dusted.

At St. Paul the experiment was more extensive but there was less rust. These trials were made in two fields. The first, field number 1, was adjacent to an artificially inoculated rust nursery. In all probability this accounts for the earliness and the irregularity of the infection. A trace of rust was already present in all of the plots at the time the wheat was flowering. By June 16 all culms were infected. The stages of development of the wheat on the dates the dust was applied are as follows: June 20, flowering; June 25, flowering to milk; July 3, milk; July 7, milk to soft dough, and July 13, soft dough. On July 16, when the final rust notes were taken, the wheat was in the hard dough stage. It was approximately mature by July 20. Field 2 was sown later than field 1 and was located about a half mile from the rust nursery. Traces of rust did not appear in this field until about July 16. At that time the wheat varied from the flowering to the milk stage. It was ripe when the final rust notes were taken. The results obtained in these two fields are presented in tables 2 and 3.

From a study of the data in these two tables, it is apparent that stem rust was controlled only when the dust was applied at a certain stage in the development of the host and its parasite. On one plot, plot 11 (table 2), in which the dusting was discontinued too early, stem rust appeared just before the straw hardened, even though five applications were made. On the other hand, in certain other plots (table 3), the dust apparently was applied too late to be effective, although very little rust was visible when the dust was applied.

At Crookston and Morris the plots were dusted too late. Precipitated sulphur dust was applied to the Crookston plots at five-day intervals at the rate of 150 pounds per acre. The first application of dust was made when the wheat was in the early milk stage, July 16. At that time there was no

TABLE 2.—*Results of dusting Marquis wheat in Field 1, University Farm, St. Paul, Minn., with precipitated sulphur at the rate of 50 pounds per acre, in 1925*

Plot number	Date of dust application					Percentage of stem-rust severity	
	June		July				
	20	25	3	7	13	July 16	July 20
1	×	×	×	×	×	5	5
2	–	×	×	×	×	5	5
Check	–	–	–	–	–	5	5
3	×	×	×	×	×	10	5
4	–	×	×	×	–	5	5
Check	–	–	–	–	–	5	5
5	–	×	×	–	–	5	5
6	×	–	×	–	–	5	5
Check	–	–	–	–	–	5	5
7	–	×	–	×	–	10	10
8	–	×	–	–	–	15	15
9	–	–	–	–	–	15	20
Check	–	–	–	–	–	15	20
10	–	–	–	×	–	25	30
Check	–	–	–	–	–	60	65
11	×	×	×	×	×	15	65
Check (alley)	–	–	–	–	–	60	65
Check	–	–	–	–	–	30	40
12	–	×	×	×	×	10	40
13	×	×	×	×	–	5	40
Check	–	–	–	–	–	5	30
14	–	×	×	×	–	5	10
15	–	×	×	–	–	5	5
Check	–	–	–	–	–	5	5
16	×	–	×	–	–	5	5
17	–	×	–	×	–	5	5
Check	–	–	–	–	–	5	5
18	–	×	–	–	–	5	5
19	–	–	×	–	–	5	5
Check	–	–	–	–	–	5	5
20	–	–	–	×	–	5	5

rust on the wheat peduncles, but it had appeared on them in all plots by July 19. On July 26 there was 85 per cent to 95 per cent stem-rust severity on all culms in both dusted and non-dusted plots. Since the minimum incubation period is about five days, it was apparent that the rust had already penetrated the wheat plants before the dust was applied. The results obtained at Morris were essentially the same as those at Crookston.

TABLE 3.—*Results of dusting Marquis wheat in Field 2, University Farm, St. Paul, Minn., with precipitated sulphur at the rate of 50 pounds per acre, in 1925*

Plot	Date of dust application						Per cent of stem-rust severity
	July				August		
	16	21	25	30	3	10	August 11
1	×	×	×	×	×	×	trace
2	×	×	×	×	–	–	trace
Check	–	–	–	–	–	–	45
3	×	×	×	–	–	–	5
4	×	×	–	–	–	–	15
Check	–	–	–	–	–	–	45
5	×	–	–	–	–	–	10
6	×	×	×	×	×	–	5
Check	–	–	–	–	–	–	25
7	–	×	×	×	×	×	50
Check	–	–	–	–	–	–	50
8	–	–	×	×	×	–	50
Check	–	–	–	–	–	–	60
9	–	–	–	×	×	–	50
Check	–	–	–	–	–	–	40
10	–	–	–	–	×	–	40
Check	–	–	–	–	–	–	50

Experiments also were made at Glasston and Tolley, North Dakota. The dust was applied at the rate of 50 pounds per acre. In different plots, 1, 2, 3, and 4 applications were made at 5-day intervals. In most cases the dusting was begun when the wheat was in the milk stage. Here, too, infection apparently had already occurred before the first applications were made. At harvest time there was no appreciable difference between the percentages of rust severity in the dusted plots and those in the checks except in a very late field at Tolley, in which dusting was begun at heading time. In this field two applications of dust reduced the percentage of rust severity from 75 per cent in the check plots to 15 per cent in the treated plots.

The results of these preliminary experiments indicate clearly that, under certain conditions, sulphur dust does control stem rust, even in the presence of a severe epidemic. However, the dust seemed to have little or no effect on the development of rust pustules after the pathogene had entered the host. Furthermore, it did not seem effective for more than a few days after it had been applied. Timeliness and frequency of applica-

tion were the critical factors. The best time to begin dusting appeared to be when the peduncles of the wheat plants first became fully exposed. Although one and two applications effectively controlled rust in a few cases, several applications made at 5-day intervals, the first when the wheat was heading, seemed to be necessary to insure rust control.

It was apparent that further experiments were needed to determine the relative effectiveness of different kinds of dusts and to devise the most economical program of applications for rust control. Therefore, the experiments were continued in 1926.

EXPERIMENTS IN 1926

In 1926 tests were made at St. Paul, Morris, and Crookston, Minnesota. At St. Paul two dusting programs were used, one similar to that used at Morris and Crookston, and the other in which experiments were made with five kinds of commercial sulphur dusts[3] applied at three rates: 50, 100, and 150 pounds per acre at each application. At Morris and Crookston[4] two kinds of dust were applied, Kolodust and Anchor Brand (flowers of sulphur), at the rate of 50 pounds per application per acre. All of the plots were replicated three times. The experiments were arranged to determine the most desirable brand of dust, the proper time to begin dusting, the smallest number of dustings that would control rust, the most satisfactory interval between dustings, and the effect of different rates of application.

The schedule followed in the experiments at Crookston is given in table 4. Similar dusting programs were followed at Morris and at St. Paul. But in these more southern latitudes the dusting was begun and discontinued 10 days earlier than at Crookston. The first application of dust was made approximately at flowering time. As indicated in table 4, 1, 2, 3, and 4 applications, respectively, were made during each of three different time periods in the development of the crop. Applications also were made at 3-, 5-, 7-, 9-, and 11-day intervals; and in one case the dust was applied to the soil only.

Some rust developed in the late plantings at St. Paul, but there was very little in the plots at Morris or in the early-sown plots at St. Paul. The best results were obtained at Crookston, as more rust developed there than

[3] Kolodust, sold by the Niagara Sprayer Co., Middleport, N. Y.; Anchor Brand dust, sold by the Stauffer Chemical Co., Houston, Texas; Sulphur Smoke, sold by the Nitrate Agencies Co., Bayonne, N. J.; Brooklyn Brand (No. 300–7), sold by Battele and Renwick, New York City; No. 300–7 sulphur dust, sold by National Sulphur Co., New York City.

[4] The work at Morris was done in cooperation with Mr. R. O. Bridgford; at Crookston in cooperation with Mr. R. S. Dunham.

TABLE 4.—*Dusting program at Crookston, Minn., in 1926*

TABLE 4.—*Dusting program at Crookston, Minn., in 1926*

Plot No.	Kind of dust	Number of dustings	July 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
1	"Kolo"	Check																														
2	"	1										×																				
3	"	1															×															
4	"	1																				×										
5	"	2										×					×															
6	"	2										×							×													
7	"	2										×									×											
8	"	Check																														
9	"	3					×					×					×															
10	"	3										×					×					×										
11	"	3															×					×				×						
12	"	4					×					×					×					×										
13	"	4										×					×					×				×						
14	"	4															×					×				×						×
15	"	Check																														
16	"	Continuous					×			×			×			×			×			×			×			×			×	
17	"	"					×					×					×					×				×						×
18	"	"					×							×							×						×				
19	"	"					×									×								×							
20	"	"					×											×										×			
21[1]	"	"					×			×			×			×			×			×			×			×			×	
22	"	Check																														
23	"	–			Before rain																											
24	"	–			After rain																											
25	"Anchor"	Continuous					×			×			×			×			×			×			×			×			×	
26	"	"					×					×					×					×				×						×
27	"	"					×							×							×						×				
28	"	"					×									×								×							
29	"	"					×											×										×			
30[1]	"	"					×			×			×			×			×			×			×			×			×	
31	"	–			Before rain																											
32	"	–			After rain																											
Precipitation in inches				.06				tr		.26	.28					.17					.17		.09	.04	.21							

[1] Dust applied on soil only.

at any of the other stations. The schedules of application followed at each station and the results obtained are given in tables 5 and 6.

There was too little rust in the plots at Morris and in the early-sown plots at St. Paul to permit definite conclusions. Yield tests were made but, owing to a severe drought in May, the stands were so irregular that in many cases there was a difference of 30 per cent between the yields of different replications.

The late field at St. Paul was sown on May 17. It was not injured so severely by the drought and became moderately infected with stem rust. The wheat headed July 10 and the first pustules of rust appeared July 21. There was rust on the peduncles August 2. All of the culms were infected in the check plots. The effect of dusting on the percentage of stem rust at harvest time is given in table 5.

A comparison of the amount of rust in plots 22, 25, 28, 32, and 35 indicates that "Kolodust" was the most effective of the dusts tested, with the possible exception of "Sulphur Smoke." The 50-pound applications of Kolodust seemed to control the rust as well as 150-pound applications, but there was not enough rust in the plots for a conclusive demonstration.

At Crookston there was enough rust in the check plots to determine clearly the effect of the different dustings. As the 1925 experiments had indicated that dusting would not be effective if begun after the wheat had passed the flowering stage, most of the plots at Crookston, in 1926, were dusted first at blossoming time. The wheat was sown on April 16; it headed on July 8; blossomed on July 10; and was ripe on August 10. The first pustule of rust appeared on July 11. The effect of dusting on the amount of rust at harvest time and on the yield is summarized in table 6. The amount of stem rust at harvest in plots 11 and 14 indicates that equally favorable results would have been obtained had the first application been made on July 15, because the rust developed about a week later at Crookston in 1926 than in 1925.

Evidently no fixed rule can be followed regarding the best time to begin dusting. The experimenter is distracted by the desire on the one hand to dust early and insure rust control, and on the other hand to dust late and save dust. Seasonal fluctuations and isophane differences make it impossible to recommend a definite date which would be equally applicable in all seasons and in all parts of the spring-wheat area. Theoretically, the most satisfactory time to begin dusting in a given region is when stem rust first can be found on wheat. But this criterion can not be used in practice unless the rust development is watched by trained observers. The most promising solution of the problem is to recommend dusting at a certain growth stage of the wheat plant. In the spring-wheat area stem rust, as a

TABLE 5.—*Results of dusting Marquis wheat with five different brands of sulphur in late-sown plots, at St. Paul, in 1926*

Plot No.	Kind and amount of dust per acre	Date dusted	Per cent stem rust severity at harvest time		
			Plots		
			A	B	C
1		Check	5	10	5
2		7/17	5	8	5
3	Kolodust	7/22	5	5	tr
4	50 pounds	7/27	7	8	5
5		8/1	8	5	3
6		7/17, 22	tr	2	tr
7		7/17, 24	tr	2	5
8		7/17, 22, 27	tr	tr	tr
9		7/17, 24, 31	5	3	3
10		7/21, 24, 27, 29, 8/4	4	5	4
11		Check	7	10	15
12	Kolodust	7/17	5	10	6
13		7/22	5	15	5
14	150 pounds	7/27	5	2	6
15		8/1	15	10	2
16		7/17, 22	3	5	1
17		7/17, 24	10	10	2
18		7/17, 22, 27	5	3	tr
19		7/17/24, 31	5	3	tr
20		After rains	20	2	3
21		Check	8	10	8
22	Kolodust	7/12, 17, 22, 27, 8/1, 7	tr	tr	tr
23	100 pounds	7/12, 19, 26, 8/2	5	5	4
24		7/12, 22, 8/1	tr	5	tr
25	Anchor	As No. 22	8	8	8
26	100 pounds	As No. 23	8	8	8
27		As No. 24	8	10	4
28	Smoke	As No. 22	2	3	5
29	100 pounds	As No. 23	3	5	8
30		As No. 24	2	3	10
31		Check	5	8	10
32	National Sulphur	As No. 22	2	3	10
33	Co. 100 pounds	As No. 23	8	8	5
34		As No. 24	5	6	5
35	Battele & Renwick	As No. 22	3	2	5
36	100 pounds	As No. 23	4	6	8
37		As No. 24	8	4	3

rule, does not become abundant until after blossoming time. In all of our experiments entirely satisfactory results were obtained by applying the first dust at this time. Therefore, until further experiments have been made, blossoming time is recommended as the best time to begin dusting.

The most satisfactory interval between dustings seems to be from 5 to 7 days. A comparison of the results obtained in plots 16, 17, and 18 (Table 6) shows that applications at 5-day and 7-day intervals will control rust as effectively as those at 4-day intervals. In all of the replications in plots

TABLE 6.—*Results of dusting Marquis wheat with Kolodust and flowers of sulphur at the rate of 50 pounds per acre at Crookston, Minn., in 1926*

Plot No.	Date dusted in July	Per cent rust severity						Yields in grams from Plots A		Grade
		July 29			August 7					
		Plots			Plots			2 sq. yd.	200 seeds	
		A	B	C	A	B	C			
1	Check	15	8	–	75	65	–	297	49.75	3 DN
2	10	5	tr	–	70	65	–	311	55.60	1 DN
3	15	5	3	–	70	55	–	298	59.40	1 DN
4	20	10	6	–	70	45	–	261	55.05	1 DN
5	10, 15	tr	tr	–	55	35	30	304	61.15	1 HS
6	10, 17	tr	4	1	35	35	7	326	63.65	1 HS
7	10, 19	tr	2	4	40	45	15	373	65.15	1 HS
8	Check	5	5	12	70	50	45	315	56.70	2 DN
9	5, 10, 15	tr	tr	4	45	20	30	339	64.25	1 HS
10	10, 15, 20	tr	tr	tr	5	2	10	274	59.30	1 HS
11	15, 20, 25	2	tr	3	5	2	2	331	64.75	1 HS
12	5, 10, 15, 20	tr	tr	tr	5	3	2	289	62.35	1 HS
13	10, 15, 20, 25	tr	tr	tr	tr	2	2	410	65.10	1 HS
14	15, 20, 25, 30	tr	tr	1	2	2	2	302	64.55	1 HS
15	Check	5	1	6	25	5	35	326	60.70	1 DN
16	5, 8, 11, 14, 17, 20, 23, 26, 29, 8/2	tr	tr	tr	tr	tr	3	339	66.80	1 HS
17	5, 10, 15, 20, 25, 30	tr	4	tr	tr	tr	3	373	69.15	1 DN
18	5, 12, 19, 26	tr	1	tr	tr	tr	tr	338	61.50	1 N
19	5, 14, 23, 30	tr	1	tr	1	2	3	371	65.30	1 N
20	5, 16, 27	tr	5	6	1	5	5	438	64.70	1 RS
21	As No. 16 but on soil only	3	8	5	3	40	45	409	65.75	1 RS
22	Check	5	10	14	30	65	65	396	61.10	1 RS
23	—	8	5	7	20	60	65	334	63.60	1 RS
24	After rain	tr	1	tr	2	2	3	341	64.00	1 RS
25	As No. 16	10	1	2	5	tr	tr	373	61.05	1 DN
26	5, 10, 15, 20, 25, 30	5	1	3	10	3	10	382	61.55	1 HS
27	5, 12, 19, 26	5	6	4	15	20	10	403	57.50	1 HS
28	5, 14, 23	5	4	5	30	20	35	389	56.85	1 DN
29	5, 16, 27	10	8	5	55	40	40	410	55.90	1 DN
30	As No. 21	8	–	10	60	40	45	325	59.20	1 DN
31	—	5	–	3	65	–	10	397	57.40	1 DN
32	After rain	1	–	3	1	–	5	390	62.25	1 HS

19 and 20, dust applied at 9- and 11-day intervals controlled the rust satisfactorily, but more evidence is needed to be sure that applications at such wide intervals will afford consistent control.

In the experiments at Crookston, 3 or more applications of Kolodust at the rate of 150 pounds per acre for each application controlled stem rust sufficiently for all practical purposes. Two applications greatly reduced the amount of rust and delayed its appearance. One dusting seemed to delay the appearance of the rust (Table 6, plots 2 and 3).

As shown in table 6 and figure 1, there was a noticeable difference in the yield of dusted and non-dusted plots. The preventable loss due to stem

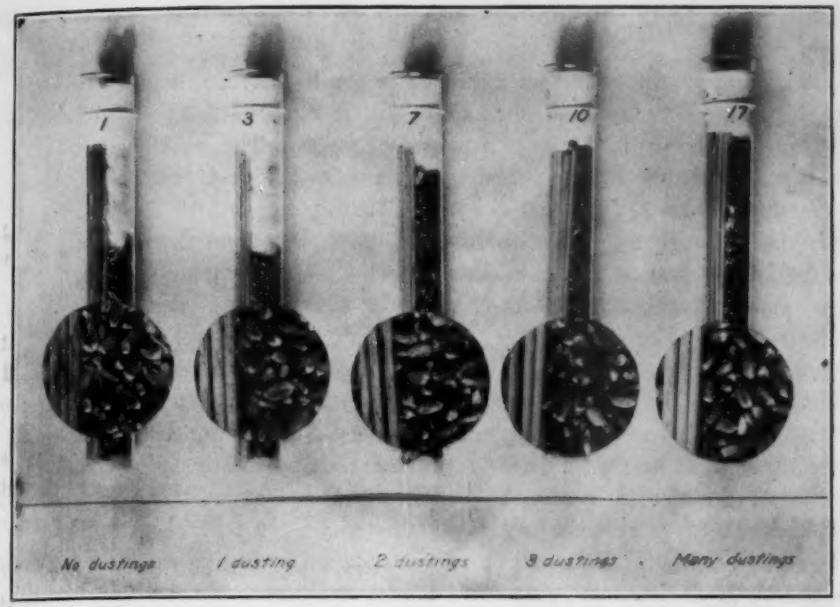

FIG. 1. The effect of sulphur dust on the percentage of stem rust and consequent yield, and quality of grain in wheat plots at Crookston, Minn., in 1926. The grain in the test tubes is the yield from 50 head samples.

Plot No.	Date dusted	Per cent of rust at harvest	Yield in bushels per acre	Grade
1	No dust applied	75	22.0	3 DN
3	July 15	70	24.5	1 DN
7	July 10, 19	40	29.5	1 HS
10	July 10, 15, 20	5	30.8	1 HS
17	July 5, 10, 15, 20, 25, 30	trace	34.5	1 DN

rust at Crookston in 1926 was approximately 25 per cent. In other words, dusting with sulphur increased the yield 30 per cent.

DISCUSSION AND CONCLUSIONS

Stem rust of wheat can be controlled by dusting the growing plants with a suitable sulphur dust. The technique should not be much more difficult than that required for dusting fruit and vegetable crops. No new principles are involved. The essentials for success are the right kind of dust and its opportune and proper application. Satisfactory dusts are available at reasonable prices; and, apparently, relatively small amounts,

properly applied, will protect wheat against destructive outbreaks of stem rust.

Two important problems, however, must be solved: Effective dusting machines must be devised, and, above all, it must be ascertained whether dusting will be profitable over a period of years. The ingenuity of manufacturers probably can be relied upon to solve the first problem, although any one familiar with wheat fields will readily appreciate the fact that it may be difficult to perfect a machine capable of dusting quickly and properly the two or three million wheat stalks in an acre of land. To dust small experimental plots thoroughly with a hand-operated duster is relatively easy; to dust larger fields thoroughly with a large machine is quite another matter. If dusting is to be a practicable method of rust control, it will, of course, depend finally on the average net profits to the farmer. In this respect the problem is no different from that involved in any other spraying and dusting problem. It would be advantageous if the onset of rust attacks and the probability of epidemics could be predicted with some degree of certainty. Whether this ever will be possible is not yet entirely clear. About all one feels justified in saying now is that even in severe epidemics stem rust can be practically and sufficiently controlled in experimental plots by dusting. Whether it can be controlled profitably by the farmers of the spring-wheat area is a question to be answered by future experiments.

SUMMARY

1. Field experiments were made at several places in the spring-wheat area in 1925 and 1926 to determine the practicability of controlling stem rust of wheat with sulphur dust. When the dust was applied properly, stem rust was effectively controlled even in the presence of severe natural epidemics.

2. Of the five different commercial brands of dust used, Kolodust was the most effective.

3. Dusting should begin when stem rust first becomes noticeable in wheat. Usually in Minnesota and North Dakota the dusting program need not be started until the wheat is in blossom.

4. The most satisfactory interval between dustings seemed to be five days. There is some evidence that rust may be controlled by dusting at ten-day intervals, but more experiments are needed to determine whether sulphur dust will adhere to wheat for this length of time in all kinds of weather.

5. Three or more dustings seem to be necessary to insure rust control sufficient for practical purposes. One or two dustings may control rust under certain conditions.

6. The most desirable rate of application has not yet been determined. Applications of 150 pounds each per acre controlled rust readily, and there is some evidence that 50 pounds or less may be sufficient.

7. In 1926 the dust treatment apparently increased the yield at Crookston, Minnesota, about 30 per cent. But even this gain would not cover the cost of three applications at the rate of 50 pounds per acre.

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DISEASES OF ECONOMIC PLANTS IN PERU[1]

E. V. Abbott

Our scientific literature contains very few reports on the diseases of economic plants in Peru. From time to time, popular articles concerning certain fungous diseases have appeared in various monthly journals published in Lima, but the writer has not been able to find any paper presenting a systematic survey of the diseases of the country. The English literature relating to the subject appears to be limited to a few papers dealing largely with the rust fungi which have been collected by botanical expeditions.

The diseases herein reported are those which have been identified by the writer since the establishment at Lima, early in 1927, of the agricultural experiment station of the Sociedad Nacional Agraria (National Agrarian Society) of Peru. While it is not expected that this is a complete list of all the diseases extant in the country, it is believed that the more common diseases of the important crops are included, since in making the survey visits have been made to nearly all of the principal agricultural sections of the country.

For the purposes of this paper, Peru may be conveniently divided into three geographical regions: the coast, the sierra, and the montaña. The coast includes the narrow, western slope of the Andes mountains, where rain never falls or is so rare as to be of no importance in agriculture. All crops, therefore, are grown under irrigation. The cultivated land of this region is limited to some twenty-five or thirty narrow but fertile valleys, each separated from the other by a stretch of barren, sandy desert. Instead of being tropical, as might be expected from its geographical position, the climate of the coastal zone is temperate, due to the cold Humboldt ocean current which flows from the South. Cotton and sugar cane are the major export crops, while rice, corn, potatoes, fruits, and vegetables are grown for domestic consumption.

The sierra comprises the plateaus and highland valleys of the Andes, the elevation of the cultivated lands varying from about 6,000 to 13,000 feet above sea level. There is a wide range of temperatures, depending upon the elevation. Although in many sections sufficient rain falls during the year for crop needs, irrigation is a common practice. Wheat, barley, corn, coca (*Erythroxylon coca*), and potatoes are the principal crops or the sierra.

The region referred to as the montaña lies east of the Andes mountains and comprises the valleys of the headwater rivers of the Amazon. The

[1] Contribution from the Experiment Station of the National Agrarian Society, Lima, Peru. Published with the approval of the Director.

elevation varies roughly from 1,500 to 6,000 feet above sea level. While climatic conditions are generally tropical, with heavy rainfall during about six months of the year, irrigation is practiced in some sections. Sugar cane, cotton, coffee, and tropical fruits constitute the crops of most importance.

The diseases included here are listed by hosts rather than according to the scientific classification of the causal organisms.

SUGAR CANE

1. *Mosaic.* The first positive identification of the mosaic disease of sugar cane in Peru was made by the writer in some plots of cane held in quarantine at Lima, in July, 1927. The following November it was found in commercial fields a short distance from Lima. A survey of the sugar haciendas of the Lima region has shown that the disease is generally distributed in this section, the infection in different fields varying from less than one per cent to 90 per cent. Counts have not shown more than 15 per cent infection with the exception of one hacienda, and fortunately the growing of cane is to be discontinued there this year. The varieties affected include Bourbon or white cane, Louisiana Purple, and some varieties of Barbados.

The mosaic was introduced into commercial cane fields in the Lima region about eight years ago and became distributed before the disease was known here. The original source of the disease is said to have been stalks of cane introduced from Argentina.

Although visits have been made to all of the principal cane-growing valleys of the coast and to three in the montaña, up to the present time neither the writer nor other representatives of the experiment station have found mosaic outside of the region of Lima.

2. *Red rot* (*Colletotrichum falcatum* F. A. Went). Red rot occurs fairly commonly in the coastal valleys, but the losses caused are seldom of great importance. Only one instance of serious loss caused by this disease has come to the writer's attention, this during the present year in an unidentified variety of cane.

3. *Eye spot* (*Helminthosporium ocellum* Faris). Although eye spot is not uncommon both on the coast and in the montaña, it is seldom of much importance. A heavy infection of Bourbon cane was observed during 1927 in the valley of Oxapampa of the montaña.

4. *Ring spot* (*Leptosphaeria sacchari* Van Breda de Haan). Ring spot is more widely distributed in Peru than the eye spot. Although the disease may be found in almost any field of cane, when heavy infections occur they are usually limited to plants in a small area. Two cases of severe leaf injury by this disease were reported during 1927, one from the coast and one from the montaña. The plants were nearly mature, however, so that only slight loss resulted.

5. *Rind rot* (*Melanconium sacchari* Mass.). This disease occurs wherever cane is grown in Peru. It is most prevalent in fields which have been badly damaged by the stalk borer.

6. *Root disease.* Cane suffering from the root-disease "complex" has been observed both on the coast and in the montaña. Bourbon cane growing in heavy soils appears to be more susceptible than varieties of Barbados. Although a study of the problem is in progress, it is impossible to state at present what factors are of most importance. In the field where root disease is present, the characteristic growth of *Marasmius* sp. is often observed, while root pitting, presumably caused by soil animals, is common. In culturing rotted cane roots in the laboratory, *Trichoderma koningi* Oud. and species of Marasmius, Rhizoctonia, and Fusarium are most frequently encountered. Pythium has not yet been isolated.

7. *Sheath disease* (*Chaetomella sacchari* Delacr.). This fungus occurs commonly on old leaf sheaths of sugar cane in Peru, but it is of no economic importance.

8. *Cold chlorosis.* During the winter months from June to December, the Bourbon cane suffers to a marked degree from the cold, particularly in the southern valleys of the coast. At this season of the year it is not unusual to see fields of Bourbon cane in which the normal green color has almost entirely given way to a sickly yellow, and on many leaves the elongate, white spots, characteristic of extreme cold chlorosis, may be found. When a field of Bourbon cane is seen growing next to one of a Barbados variety, the lesser degree to which the latter is affected by cold is very striking.

9. *Other chloroses.* A chlorotic condition of cane, apparently very similar to the Pahala blight described by Lee and McHargue,[2] has been observed several times on the coast of Peru. Plants showing this chlorosis occur in rather salty soils. There has been no opportunity to determine whether the chlorosis could be corrected by the application of manganese or iron compounds either to the soil or to the plants.

COTTON

1. *Wilt* (*Fusarium vasinfectum* Atk.). Wilt is known to occur in four valleys of the coast section and is of importance in two, the Rimac and Chancay. Tanguis, a cotton variety, originated about ten years ago by a Peruvian grower, whose name it bears, and the one most extensively grown in the country, was long believed to be resistant to the disease. If it was originally resistant, it appears to have lost this property in recent

[2] Lee, H. Atherton, and J. S. McHargue. The effect of a manganese deficiency on the sugar cane plant and its relationship to Pahala blight of sugar cane. Phytopath. 18: 775–786. 1928.

years. During 1928 the writer found fields of Tanguis with as high as 75 per cent infection by wilt. Tanguis is much more resistant, however, than Pima, Egyptian, or American Upland cotton. Infected plants of these varieties are usually killed during the first year, while the Tanguis may not show serious effects of the disease until the second season. In some instances diseased plants will continue to produce a crop for three years, although the yield is reduced.

2. *Sore shin* (*Corticium vagum* Berk. and Curt.). Sore shin or damping off of young plants occurs wherever cotton is grown in Peru, being most prevalent in heavy soils, and in cotton planted early in the spring. From five to ten replantings are necessary in some instances.

3. *Leaf spot* (*Alternaria tenuis* Nees.). This leaf disease is general on cotton in Peru. While it is usually not of major importance, a few instances have been noted where it resulted in partial defoliation of the plants.

4. *Leaf, bract,* and *boll spot* (*Helminthosporium gossypii* Tucker). This disease is widely distributed in the country, but is of minor importance.

5. *Mildew* (*Ovulariopsis gossypii* Wakef.). Mildew has been observed in the Department of Piura, extreme north coast, and in the vicinity of Lima. Heavy infections may occur in Piura on cotton growing in moist soils, causing curling of the leaves and premature falling. In 1927 the disease was rare, while in 1928 the heaviest infection in many years occurred.

6. *Boll rots.* Boll rots of cotton caused by parasitic organisms are not of importance in Peru. Where fungous infection of bolls occurs it is usually by saprophytic or weakly parasitic organisms which enter through insect punctures or other mechanical injuries. Bolls so rotted seldom exceed 10 per cent of the total crop, and the percentage is usually much less. The fungi which are found most commonly on or within rotting bolls are *Rhizopus nigricans* Ehr., *Aspergillus niger* Van Tieg., *Hormodendrum cladosporioides* (Fres.) Sacc., and *Fusarium* sp. *Diplodia gossypina* Cke. is rare.

Up to the present time anthracnose (*Glomerella gossypii* (E. A. Southworth) Edg.), or the bacterial leaf and boll disease (*Bacterium malvacearum* EFS.), has not been observed in Peru by the writer.

7. *Growth disorder.* A condition closely approximating the tomosis or leaf-cut described by Cook[3] in Haiti has been observed in the Departments of Piura and Lambayeque in the north-coast section. The trouble is characterized by the crinkled and abnormally developed leaves, the margins of which often appear to have been cut or broken very irregularly. An entire plant or only a few leaves may be affected. Young plants appear to be particularly susceptible, and, if the main growing shoot is involved, they

[3] Cook, O. F. Leaf-cut, or tomosis, a disorder of cotton seedlings. U. S. Dept. Agr., Bur. Plant Indus. Circ. 120: 29–34. 1913.

may be seriously stunted. Chlorosis of diseased leaves is not marked. Where the disease has been observed by the writer, cotton of the Upland type was affected to a much greater extent than Pima or the native Tanguis.

The observations reported here have been made while on brief trips to the sections mentioned, no opportunity having presented itself for continuous study through a growing season.

8. *Root knot* (*Heterodera radicicola* (Greef) Muell.) is known to occur in one valley of the coast.

CORN

1. *Leaf spot* (*Cercospora sorghi* Ell. and Ev.). The **Cercospora** leaf spot, widely distributed on corn in Peru, is probably the crop's most important fungous disease. It often causes a severe firing or drying of the leaves before the plants are mature.

2. *Leaf blight* (*Helminthosporium turcicum* Pass.). Although leaf blight is as of general occurrence as the **Cercospora** disease, it is of less economic importance.

Both the **Cercospora** and the **Helminthosporium** are present throughout the year on *Holcus halepensis* L., which has come to be one of the worst weeds in cultivated fields on the coast.

3. *Rust* (*Puccinia sorghi* Schw.) occurs wherever corn is grown in Peru, but it is seldom of importance. Heavy infections involving 100 per cent of the plants in a field have been observed only in the vicinity of Cuzco.

4. *Smut* (*Ustilago zeae* (Beckm.) Ung.). Smut is general on corn, but is of minor importance.

5. *Cob rot* (*Basisporium gallarum* M. Molliard). Cob rot has been observed by the writer only in the vicinity of Lima, where it may affect 10 to 20 per cent of stored corn.

6. *Seedling and root rots.* A study of these diseases is now being made. Preliminary results indicate that species of **Fusarium** are the most important causal agents. Infection of seed corn by *Fusarium moniliforme* Sheldon is common.

WHEAT

1. *Stem rust* (*Puccinia graminis* Pers.). The cultivation of wheat in Peru is at present limited entirely to the sierra, largely because of the severity with which the crop is attacked by stem rust on the coast. It is said that rust has made the cultivation of wheat on a commercial scale on the coast impossible for more than a century.

Rust also occurs in epidemic form in the sierra, but the disease develops sufficiently late in the growing season to enable the plant to reach maturity. The traveler in the sierra will often see crosses and wreaths of flowers in

the wheat fields cultivated by the Indians, placed there as a means of invoking divine protection for the crop against rust and smut.

During the past year, sixty varieties of wheat, obtained through the courtesy of the United States Department of Agriculture and of several of the state experiment stations in the United States, were tested for rust resistance at the experiment station. Only four of these, Pusa, White Federation, Kanred, and Hope produced mature grain. In the case of Pusa this was due to its earliness rather than to any ability to resist rust infection. Although the other varieties mentioned rusted heavily, a few heads were partially filled.

2. *Leaf rust* (*Puccinia triticina* Eriks.) is general on wheat in Peru and occurs in epidemic form.

3. *Covered smut* (*Tilletia laevis* Kuehn) is general in the sierra. According to information received from farmers in various parts of that region, the loss from the disease in some instances may amount to 50 per cent of the crop, but these reports have not been verified. Where the disease has been observed by the writer near Arequipa and Cuzco, the infection did not exceed 15 to 20 per cent. Seed treatment for control is seldom practiced.

4. *Loose smut* (*Ustilago tritici* (Pers.) Rostr.) is not uncommon, but is usually of minor importance.

5. *Other diseases.* The Oidium stage of *Erysiphe graminis* DC. was present throughout the season of 1928 in the fields of the experiment station. *Helminthosporium sativum* Pam., King, and Bakke has been found associated with black point of wheat grains received from the sierra. Specimens of *Fusarium culmorum* (W. Sm.) Sacc. on seedlings, and what appears to be *Rhynchosporium graminicola* Hein. on nodes of mature plants, have been received from the same section.

BARLEY

1. *Stem rust* (*Puccinia graminis* Pers.). Stem rust occurs wherever barley is grown in the country, and, while the disease usually is not so serious as on wheat, it causes a considerable annual reduction in yield. Several varieties imported from the United States during the past year suffered less from stem rust than the principal variety now grown in the country.

2. *Net blotch* (*Helminthosporium teres* Sacc.). Net blotch, general on barley in Peru, often occurs in severe form. In 1927 the barley at the experiment station farm was a failure because of this disease. During the past year field tests have been made with eighteen varieties received from experiment stations in the United States, of which the following suffered much less from the disease than did the variety at present grown here, *viz*, Oderbrucker, Heil's Hanna, Beardless 72, Horsford, Pedigree 5–1 (Wisconsin), and Daniels.

3. *Leaf scald* (*Rhynchosporium secalis* (Oud.) Davis). A leaf disease caused by a species of Rhynchosporium, probably *R. secalis* (Oud.) Davis, is general on barley and sometimes causes a severe leaf blighting.

4. *Loose smut* (*Ustilago nuda* (Jens.) Kell. and Sw.). Loose smut of barley is not uncommon, but is usually of minor importance.

5. *Powdery mildew* (*Erysiphe graminis* DC.). The conidial stage of what is believed to be *Erysiphe graminis* DC. is general on barley.

ALFALFA

1. *Leaf spot* (*Pseudopeziza medicaginis* (Lib.) Sacc.). This disease has been observed only on the coast. While it is present throughout the year, the heaviest infection begins in October and continues through November, resulting at times in almost complete defoliation of the plants. During the other months of the year it is of little importance.

2. *Leaf spot* (*Pleosphaerulina briosiana* Poll.). Although this leaf spot is general on alfalfa, it is of minor importance.

3. *Rust* (*Uromyces medicaginis* Pass.) is common, but only in rare instances does it cause damage worthy of note.

4. *Downy mildew* (*Peronospora trifoliorum* de Bary) is general on alfalfa, particularly in young stands.

POTATOES

1. *Late blight* (*Phytophthora infestans* (Mont.) de Bary) is of universal occurrence on potatoes in Peru and is the one disease of this crop for which control measures are employed. Spraying is a general practice in the coast section, while in the sierra the disease is generally attributed to the weather, and consequently no effort is made to control it. Growers in that section state that in years when cool, wet weather prevails during the growing season, from 50 to 75 per cent of the crop may be lost from "hielo," the local name for the disease, which means ice or frost. Since freezing temperatures are known to occur at times in some parts of the sierra during the growing season, the writer is unable to say how much of this loss may be due to actual freezing and how much to blight. On the coast, where the crop is sprayed, the disease is kept well in check.

2. *Powdery scab* (*Spongospora subterranea* (Wallr.) T. Johnson). Observations made by the writer and reports received from various sections, show that powdery scab is widespread in the sierra. The canker stage is of common occurrence. The disease has not been observed on the coast, its absence apparently being due to the higher temperatures prevalent in that section. In view of the fact that the coast growers import all of their seed potatoes from the sierra every year, it is only reasonable to expect

that some infected tubers would be included in the shipments and that the disease would be found on the coast if conditions favored its development.

3. *Wilt* (*Fusarium oxysporum* Schl.) is general in Peru. In the vicinity of Lima commercial fields are seldom free of the disease, and in some instances during the past season the infection was as high as 40 per cent.

4. *Virus diseases.* Mild mosaic, leaf roll, and spindle tuber. Although these diseases are common on potatoes in Peru, they are not recognized as diseases by the growers. In the coast section, where the potato crop is becoming of increasing importance, it is the common belief that the use of coast-grown tubers for seed leads to a rapid degeneration or running out of the crop, a condition attributed entirely to climatic factors. Consequently, the coast growers annually import all of their seed potatoes from the sierra.

While climatic factors may have some influence in this degeneration, the universal presence of the virus diseases leaves no doubt that they are important contributing factors. The method of choosing seed tubers at present practiced in the country offers ideal conditions for the propagation of these diseases. No plant selection is made in the field, but after the crop is harvested the tubers are separated by hand according to size and the small tubers of about one-half to one inch in diameter are set aside for seed. Although the small tubers from good hills are thus included in the seed lots, a large percentage of the product of the diseased hills is likewise set aside for propagation purposes.

In view of the fact that the important diseases of the potato on the coast are seed-borne, the question of good seed stock for this section is one worthy of careful study. Coast growers, as a rule, buy their seed potatoes in the general market of Lima without having any definite knowledge of their origin in the sierra. Studies are at present being made to determine whether tubers selected from healthy, coast-grown plants and kept free of disease, will continue to produce vigorous plants when grown for several years in the same locality.

5. Tuber rots, caused by species of Fusarium, occur commonly, especially in stored potatoes.

6. *Early blight* (*Alternaria solani* (Ell. and Mart.) Jones and Grout) is general on potatoes.

7. *Wart, Synchytrium endobioticum* (Schilb.) Perc., is known to occur in the central Andes near Jauja.

COFFEE

1. *Eye spot* (*Stilbella flavida* (Cke.) Lind.) is one of the most important fungous diseases of coffee in the Peruvian montaña. A heavy attack may result in almost complete defoliation of the plant, with the resultant loss

of the berries. The fungus also causes a rot of the berries. Fortunately such heavy infections are usually confined to a relatively few plants in scattered areas over the plantations, generally where there is excessive shade. The loss from the disease is greater in wet years.

2. *Brown spot of fruit and leaf* (*Cercospora coffeicola* B. and C.). Although widely distributed in the coffee-growing sections, this disease is of less importance than the eye spot. Its principal damage is to the fruit, infection by this fungus resulting in a partial or complete rot of the ripening berries, especially in moist and heavily shaded areas.

3. *Leaf blight* (*Corticium koleroga* (Cke.) v. Hoeh.) is general in the montaña, where it causes partial defoliation, die-back of twigs, and often death of the plant.

4. *Zonal leaf spot* (*Cephalosporium* sp.), which occurs in scattered sections of the coffee districts, is of minor importance.

5. *Wilt* (*Fusarium* sp.). A disease which exhibits all of the symptoms of the Fusarium wilts has been observed in two valleys of the montaña, but the areas involved were small. Affected plants wilt slowly, and on cutting the trunk the vascular system shows brown to black discolored areas. Two species of Fusarium have been isolated from diseased plants, but it has not yet been possible to prove their connection with the disease.

6. A leaf disease (*Colletotrichum coffeanum* Noack.) has been identified from a specimen sent from a coffee plantation on the coast.

7. *Root disease* (*Rosellinia* sp.) is of considerable importance in the Chanchamayo and Perené valleys of the interior and is known to occur in at least one other coffee district, Oxapampa. While the species of the causal fungus has not been definitely determined, the symptoms of the disease are those caused by *R. bunodes* B. and Br.

FRUITS

Although Peru affords climatic and soil conditions favorable for both tropical- and temperate-zone fruits, fruit production probably is the least developed branch of agriculture in the country. Commercial orchards of any kind are very rare, the bulk of the fruit grown for the domestic market being produced by small holders. On most of the large farms are to be found small groves with a variety of fruits which supply local needs. Of major importance among the many fruits produced in the country are avocados, citrus fruits, bananas, mangos, cherimoyas, apples, grapes, and dates.

Domestic production is insufficient to meet the demands of the local market, apples, pears, and oranges being imported in considerable quantities from the United States; bananas and pineapples from Ecuador; and apples and peaches from Chile.

AVOCADO. Of the diseases of the avocado, anthracnose (*Physalospora perseae* Dodge) is by far the most important. The distribution of the disease in the country is not definitely known, but, judging from the regularity with which it is found on fruits coming into the Lima market from various parts of the country, it appears to be widespread. In the Santa Eulalia district, one of the principal sources of Lima's supply of this fruit, anthracnose is making slow but steady headway. Scab (*Sporotrichum citri* Butl.) also is of frequent occurrence on the fruit coming into the Lima market. Blotch (*Cercospora* sp.) is common, but is of minor importance.

CITRUS FRUITS. Knot (*Sphaeropsis tumefaciens* Hedges) occurs in southern Peru on limes, but it has not been seen in other parts of the country. Dry root rot (*Fusarium* sp.) of orange has been identified from specimens received from the central coast section. The fruit rot of orange caused by *Penicillium digitatum* Sacc. may always be found in the public markets and in shipped fruit. Much of the loss caused by this fungus could be prevented by more careful handling.

BANANA. Fungous diseases of the banana are of minor importance in Peru. Anthracnose (*Gloeosporium musarum* Cke. and Mass.) is present on a large percentage of the fruit sold in Lima. Considerable rotting of market fruit is also caused by *Rhizopus nigricans* Ehr. A leaf spot (*Cercospora musarum* Ashby) is widely distributed, but is of little importance.

APPLE. Black rot (*Sphaeropsis malorum* Pk.) occurs in the vicinity of Lima, where it often causes the death of young trees. A surface bark canker (*Myxosporium corticolum* Edg.) is common, but of no economic importance. Fruit rotting caused by *Penicillium expansum* Lk. emend Thom occurs frequently in stored and shipped fruit.

MISCELLANEOUS. The following diseases and their causative organisms have been identified at different times in the field or from specimens received at the laboratory: leaf spot (*Cercospora viticola* (Ces.) Sacc.) and powdery mildew (*Uncinula necator* (Schw.) Burr.) on grape; rust (*Tranzschelia puncata* (Pers.) Arth.) and root knot (*Heterodera radicicola* (Greef) Muell.) on peach; false smut (*Graphiola phoenicis* (Moug.) Poit.) on date; rust (*Cerotelium fici* (Cast.) Arth.) on fig; rust (*Uredo cherimoliae* Lagh.) on cherimoya; and a leaf spot (*Diplodia cacaoicola* Hen.) on papaya and mango. Little information is available regarding their distribution in the country.

VEGETABLES

BEANS. The following diseases of the garden bean have been identified: anthracnose (*Colletotrichum lindemuthianum* (Sacc. and Magn.) Briosi and Cav.), from the coast; powdery mildew (*Erysiphe polygoni* DC.), from the coast; leaf spots (*Cercospora cruenta* Sacc.) from the coast, and

(*Phyllosticta phaseolina* Sacc.), general; dry root-rot (*Fusarium martii phaseoli* Burk), from the coast; stem rot (*Corticium vagum* Berk. and Curt.), from the coast; and rust (*Uromyces appendiculatus* (Pers.) Lk.), from the montaña. Of these the Corticium stem rot is of most importance. In 1927 it killed more than a hundred acres of beans near Lima.

Rust (*Uromyces fabae* (Pers.) de Bary) is common on the broadbean in the sierra, but has not been observed as yet on the coast.

TOMATO. Tomato diseases which have been identified to date, all from the coast section, are as follows: late blight (*Phytophthora infestans* (Mont., de Bary); root knot (*Heterodera radicicola* (Greef) Muell.); a fruit rot, which inoculation experiments have shown to be caused by a yeast, probably *Nematospora lycopersici* A. Schneider; and mosaic.

MISCELLANEOUS VEGETABLE CROPS. The following diseases of vegetable crops, which for the most part have been identified from the vicinity of Lima, are of frequent occurrence although usually of minor importance; leaf spot (*Alternaria brassicae* (Berk.) Sacc.), on cabbage, cauliflower, and turnip; gray mold (*Botrytis* sp.), and black stalk rot (*Macrosporium sarcinula parasiticum* Thuem.), on onion; leaf spot (*Cercospora bloxami* B. and Br.), on cabbage; leaf spot (*Cercospora beticola* Sacc.), on garden beet; leaf spot (*Septoria pastinacina* Sacc.), on parsnip; powdery mildew (*Erysiphe polygoni* DC.), on pea; and powdery mildew (*Erysiphe cichoacearum* DC.), on squash and pumpkin. The last-named disease often assumes importance.

MISCELLANEOUS DISEASES

The diseases, with their causative organisms, which have been noted on plants of relatively minor economic importance in Peru are as follows:

OATS: Loose smut, *Ustilago avenae* (Pers.) Jens., and crown rust, *Puccinia coronata* Cda.

SORGHUM: Covered kernel smut, *Sphacelotheca sorghi* (Lk.) Clint., and leaf blight, *Helminthosporium turcicum* Pass.

SUDAN GRASS: Leaf blight, *Helminthosporium turcicum*.

JOHNSON GRASS: Rust, *Puccinia purpurea* Cke., leaf blight, *Helminthosporium turcicum*, and leaf spot, *Cercospora sorghi* Ell. and Ev.

ROSE: Leaf spot, *Cercospora rosicola* Pass., rust, *Phragmidium* sp., and powdery mildew, *Sphaerotheca* sp.

WILLOW: Leaf spot, *Cercospora salicina* Ell. and Ev., and rust, *Melampsora humboldtiana* Speg.

EUCALYPTUS: Leaf spots, *Cercospora epicoccoides* Cke. and Mass.,[4] and *Macrosporium* sp.

[4] The writer is indebted to Mr. William W. Diehl, of the United States Department of Agriculture, for the identification of this species.

SUMMARY

In this paper are listed 106 diseases of economic plants in Peru, divided as follows: sugar cane 9, cotton 8, corn 6, wheat 8, barley 5, alfalfa 4, potatoes 9, coffee 7, fruits 20, vegetable crops 19, and miscellaneous plants 11. Of these diseases, 95 are caused by fungi, 5 are of virus origin and one other is believed to belong to this group, 3 are caused by nematodes, and 2 are physiological.

While it is not expected that the list includes all the diseases in Peru, it is believed that it includes those of most importance.

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THE RESPONSE OF HULLESS BARLEY TO SEED TREATMENT FOR COVERED SMUT AND STRIPE DISEASE[1]

R. H. Porter, T. F. Yu, and H. K. Chen[2]

Hulless bearded barley is a crop of considerable importance throughout the lower Yangtse valley region in China. Its adaptability to the climate and to a rotation with rice accounts for its wide usage. Crop-disease surveys in East China during the summers of 1924 and 1925 showed that hulless barley was more widely grown than the hull sorts, and that covered smut caused by *Ustilago hordei* (Pers.) K. & S. was more severe on the hulless varieties. In addition, the stripe disease caused by *Helminthosporium gramineum* (Rab.) Eriks. was generally prevalent. It was not uncommon in fields of hulless barley to find 40 per cent of the heads destroyed by covered smut and as high as 15 per cent of the plants infected with the stripe disease.

Control measures for covered smut and stripe on the hulless varieties of bearded barley have not been developed. In the United States and in Europe where extensive studies for the control of these two diseases have been carried on, the investigations have dealt only with the hull types. Using several varieties of hull barley, Tisdale, Taylor, and Griffiths (6, 7), Leukel (2), and Lambert, Rodenhiser, and Flor (1) have studied the effects of formaldehyde and numerous organic mercury compounds on covered smut. Tisdale, Taylor, and Griffiths (6) also used copper carbonate, which failed to control covered smut and apparently caused an increase in loose smut.

Preliminary trials by the senior author (4) indicated that copper carbonate might prove effective in the control of covered smut on hulless barley. Its favorable response to copper carbonate, in contrast to the response of hull barley, led to a more intensive study of the seed-treatment problem. Further, it seemed evident that covered smut was more destructive on hulless than on hull barley in East China, a condition which suggested that infection with *Ustilago hordei* might occur more readily on the former type, thereby affecting the problem of control. A closely allied problem, which has not received sufficient attention, is the effect of seed disinfectants on the yield of grain. This need of information led to an

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attempt to determine (1) the effect of seed disinfectants on covered smut and stripe of hulless barley in East China and (2) the effect of seed treatment on the yield.

The experiments to be recorded were carried on during a period of two crop years beginning in the autumn of 1925. Only hulless winter barley was used in the tests. The work was interrupted by the Nationalist Revolution in 1927, which made it necessary for the senior author to leave China. Certain phases of the project, however, are being carried on by the junior authors.

I. STUDIES WITH COVERED SMUT

Preliminary trials for the control of covered smut were begun in 1925 with seed purchased from a farmer in whose field 11 per cent of the heads were infected with covered smut. Dry fungicides used consisted of Tillantin "B," powdered copper sulphate, copper carbonate, testing 54 per cent metallic copper, and a prepared carbonate, testing 40 per cent copper. All the dusts were applied at the rate of two ounces per bushel. The liquid materials were copper sulphate (1 to 40), formaldehyde (1 to 320), Tillantin "B" (three grams per liter of water), and formaldehyde (1 to 120) at 50° C. The seed was soaked two minutes in hot formaldehyde, ten minutes in copper sulphate, one hour in Tillantin, and two hours in cold formaldehyde.

The planting plan was so arranged that every third row was a check. The rows were 16 feet long and one foot apart with 15 grams of seed per row. Seven replications of each sample were planted, making eight rows of each treatment. Before harvest, it was discovered that the soil where the plot was located was not uniform because part of it had been used as a garden. The yields, therefore, were variable, except in the case of the formaldehyde-treated seed where injury to the seed reduced the stand and the yield. The average yield of smut in the untreated rows was 6.9 per cent. With two exceptions, all of the treatments completely eliminated covered smut. Tillantin solution allowed 0.2 per cent smut, while the rows treated with commercial copper carbonate had an average of 0.5 per cent, although in the latter case all of the smutted heads, 16 in number, occurred in one row.

Tests the same season in small plots 12 x 30 feet in size were made with two dusts and one liquid treatment. The stand in all plots, except where hot formaldehyde was used, was reasonably uniform as shown by counts made in equal areas. Smut control was effective as evidenced by the following results: hot formaldehyde none, commercial copper carbonate 1.2 per cent, prepared carbonate 0.7 per cent, and the untreated 27 per cent smut. These results showed that, even with a high percentage of smut on barley, copper carbonate was able to reduce it to approximately one per cent.

Seed Treatment Trials in 1926. The studies carried on in 1926 were similar to those of 1925, except that seed was secured from three different sources and only dusts were used. In addition, nine replications were made for each treatment instead of seven. The fertility of the soil was low but more nearly uniform than in 1925. Before harvest the total number of smut-free and smutted heads per row was determined. Each row was cut and threshed separately and the weight of grain recorded in grams. The reliability of the results presented in table 1 was measured by "Students Method" in terms of odds.

The results presented in table 1 show that there is a difference in the effect of a given disinfectant on seed from different sources. For example, in one case copper sulphate reduced the smut to less than one per cent, but on two of the seed lots it allowed nearly as much as on the untreated seed. Copper carbonate and Uspulun completely eliminated smut on seed from two sources, but on seed from Kaifeng both disinfectants allowed 0.68 and 0.58 per cent, respectively. The low percentage of smut in the checks, as well as the low yields, makes it difficult to measure the relative value of the materials used, but the average effect of all four treatments on the three lots of seed is summarized below:

Uspulun gave the most effective control and the highest increase in yield on the three lots of seed, but copper carbonate was nearly as effective. Copper sulphate, in the form used in these experiments, seemed an undesirable disinfectant.

In the majority of the tests shown in table 1, the increases in yield measured in terms of odds are of some significance, but it is doubtful if these increases can be entirely attributed to smut control because the percentage of smut was always low. In some cases, however, the increase in yield was more than 25 per cent. Part of this increase may be due to the control of other barley diseases. A root rot of barley of unknown cause is common and destructive, but the number of such diseased plants was in no case excessively high, and no treatment eliminated them completely. The stripe disease was not prevalent in the seed used in these tests; therefore, the control of this disease could not have entered into the results. Inasmuch as this additional increase in yield, beyond that secured by smut control, was apparently not due entirely to the control of other diseases or to an increase in stand, it is suggested that part of it may have been due to the protection of seed in the soil from soil organisms which, on untreated seed, may invade the young seedling sufficiently to lower its vitality.

Results with Small Plots in 1926–27. Seed collected at Nanking and grown from the seed used in the fall of 1925 was used in planting the test with small plots one-half square rod in size. Each treatment was planted

TABLE 1.—*Effect of seed disinfectants on covered smut and on yield of hulless barley. Nanking, China, 1927*

Source of seed	Fungicide	Average number heads per row	Per cent smut	Yield bu. per A.		Gain bu.	Per cent increase	Odds
				Treated	Untreated			
Nanhsuchow Kiangsu Province	$CuSO_4$ Dry	242	0.87	14.7	12.7	2.0	15.8	11 to 1
	Tillantin "B"	243	0.86	13.0	13.2	-0.2	- 1.6	none
	Copper carbonate	254	0.0	14.5	13.2	1.3	10.0	3 to 1
	Uspulun	247	0.0	14.9	12.5	2.4	19.2	555 to 1
	Checks, av. of all	250	4.9		12.9			
Kaifeng Honan Province	$CuSO_4$ Dry	328	2.16	21.0	19.0	2.1	11.0	37 to 1
	Tillantin "B"	286	1.1	20.4	17.0	3.4	20.0	216 to 1
	Copper carbonate	293	0.68	19.4	17.0	2.4	14.1	30 to 1
	Uspulun	279	0.57	20.6	16.2	4.4	27.2	216 to 1
	Checks, av. of all	313	2.76		17.6			
Nanking Kianysu Province Seed used had 20 pct. smut in 1926	$CuSO_4$ Dry	251	3.3	12.6	11.7	0.9	7.7	none
	Tillantin "B"	256	0.9	12.8	10.8	2.8	26.0	416 to 1
	Copper carbonate	259	0.0	13.1	10.6	2.5	23.6	100 to 1
	Uspulun	254	0.0	13.5	11.9	1.5	12.6	8 to 1
	Checks, av. of all	251	5.9		11.2			

Fungicide	Av. pct. smut three seed lots	Av. increase bu. per acre	Per cent increase
Copper sulphate	2.1	1.7	11.5
Tillantin "B"	0.95	2.0	14.8
Copper carbonate	0.23	2.1	15.9
Uspulun	0.19	2.8	19.7
Checks	3.9		

in triplicate with every third plot as a check. The seed was weighed for each row, using 15 grams per row. Four dust treatments were used, namely, Uspulun, Tillantin "B," copper carbonate, and Tillantin-Trochenbeize. The results of this test are summarized in table 2.

TABLE 2.—*Effect of dust treatments on covered smut of hulless barley in plots containing one-half square rod repeated three times at Nanking, China, in 1927*

Treatment	Av. heads per plot	Per cent smut	Yield bu. per A.		Gain	
			Treated	Untreated	Bu.	Per cent
Copper carbonate	2043	0.0	13.0	11.1	1.9	17.1
Till.-Trochenbeize	2107	0.03	14.6	13.5	1.1	8.2
Uspulun	2172	0.76	16.3	16.1	0.2	1.2
Tillantin "B"	2530	1.65	20.7	18.7	2.0	10.7
Checks, av. of all	2149	5.2		14.9		

The data presented in tables 1 and 2 are comparable from the standpoint of smut control. Copper carbonate gave, on the average, the most effective control and Tilliantin the least effective, with the exception of copper sulphate which was not used in the plot test. Tillantin-Trochenbeize, used for the first time on hulless barley, gave almost as satisfactory control as copper carbonate. Tillantin "B" apparently is uncertain in its control of smut and for that reason is undesirable, even though in some cases it caused a marked increase in yield. The fertility of the soil used for this plot test was irregular as evidenced by the yields of the untreated plots. The soil was more fertile at one end than the other, which may account for the fact that dry Uspulun in the plot test gave the lowest increase in yield of any of the treatments, but in the rod-row tests it gave the highest increase where soil fertility was not so irregular.

II. STUDIES ON THE CONTROL OF BARLEY STRIPE

Experiental work for the control of barley stripe has been carried on by Leukel, Dickson, and Johnson (3) during the past five years, but, as in the case of covered smut, most of the studies have been made on hull varieties.

These authors have thoroughly reviewed the literature on barley-stripe control, so that no review is attempted in this paper. Recently, Rodenhiser (5), in summarizing his results covering a four-year period, stated that two dusts eliminated stripe entirely and four others were almost as effective. He also stated that the effect of certain dust fungicides on the yield was not yet known, but that no deleterious effects were noticed either on oats or hulless barley.

In the experiments reported in the following pages, an effort was made to make all of the tests as nearly uniform as possible. The solutions stood at room temperature at time of application. All of the wet treatments for a given plot were made on the same day and dried under the same conditions. Only one hulless variety was used. This was a winter barley of a bearded type. No solution was used more than once, and the seed was not immersed until the material was well dissolved, after which no stirring of the mixture took place. The seed was poured into the solution and after the required soak the fungicide was poured off and the grain dumped out on papers to dry. In addition, every row was harvested, weighed, and threshed, after counts for healthy and diseased plants were secured.

Experiments with Barley Stripe, 1925–26. The original seed used in all of the tests on barley-stripe control was hulless barley purchased from a farmer near the experimental fields of the University of Nanking. Observations in the field in the early summer of 1925 showed approximately 12 per cent of the plants infected with stripe. Only a trace of either covered or loose smut was present. This seed was used in all of the treatment tests in the autumn of that year. Seed from untreated rows showing 11 per cent stripe planted in a stripe-resistance-test plot was saved for seed and used in the fall of 1926 for all of the seed-treatment tests that year. The same disinfectants as well as the same planting plan used in the covered-smut experiments in 1925 were used for this test on stripe control. Unfortunately, the soil proved to be variable and, in addition, some of the rows lodged so badly that no accurate yield records could be secured. In some cases, the total number of plants could not be determined, and, for that reason, only the average number of stripe-diseased plants per row can be given. Four of the disinfectants, viz: copper-sulphate solution, dry Tillantin, and both hot and cold formaldehyde completely eliminated stripe. Of the other materials the average number of stripe plants per row was: 54 per cent copper carbonate, four; 40 per cent copper carbonate, three; Tillantin solution, three-tenths, and powdered copper sulphate, eight-tenths. The average number of stripe plants in the untreated rows was 12.

Results with Rod Rows in 1926–27. The materials used in the autumn of 1926 were both dry and liquid disinfectants. Some of them were fur-

nished by the China-Export-Import and Bank Co. Ltd. of Shanghai. All the dusts were applied in the same way and at the same rate as described in the foregoing for covered smut. Liquid treatments furnished by this company were made up at a concentration of 0.3 per cent and the seed was

TABLE 3.—*The effect of seed disinfectants on stripe and on yield of hulless barley, Nanking, China, 1927**

Treatment	Av. No. heads per row	Per cent stripe	Yield bu. per A.		Gain		Odds
			Treated	Untreated	Bu.	Pct.	
Uspulun-Dry 2 oz. per bu.	70	0.1	8.3	6.7	1.6	23.9	1999 to 1
Tillantin-Trochenbeize	70	1.7	8.6	7.2	1.4	19.4	344 to 1
Uspulun .3% Sol. 1 hr.	71	0.0	9.3	7.2	2.1	29.1	4.6 to 1
Tillantin-Nazzbeize .3% Sol. 1 hr.	70	0.7	7.9	7.3	0.6	8.2	7 to 1
Uspulun .3% Sol. 2 hrs.	70	0.0	8.6	7.4	1.2	16.2	8 to 1
Tillantin-Nazzbeize .3% Sol. 2 hrs.	69	0.3	8.5	7.0	1.5	21.4	555 to 1
Checks, av. of all	72	14.4		7.1			

* Materials used in this test were furnished by the China-Export-Import and Bank Co. Ltd. of Shanghai, China.

soaked for one and two hours respectively. Each treatment was replicated nine times and the checks occurred every third row, so that a treated row was always next to an untreated one. Each row was harvested separately and the yield determined in grams. The results of this test are given in table 3.

In table 3 it will be noted that, of the dry treatments, Uspulun almost eliminated stripe and gave a marked increase in yield, even though the highest yield in the entire plot was less than 10 bushels per acre. Tillantin-Trochenbeize was least effective in the control of stripe but materially increased the yield. Of the two solutions used, it appears that a two hours' application of Uspulun was beyond the maximum time since it did not give so high an increase in yield as the one-hour soak and was no more effective in stripe control. Tillantin-Nazzbeize, on the other hand, gave better control and a more significant increase in yield with the two-hour soak than with only one hour.

Results with Small Plots 1926–27. In addition to the rod-row tests, a series of ½ sq.-rod plots were planted October 18, 1926, in the same way as described for covered smut of barley on page 658. The soil proved highly fertile and the yield of the checks was high. The results of this test are summarized in table 4, in which it will be noted that none of the treatments eliminated stripe, but all reduced it more than 50 per cent with the exception of copper carbonate. The yield increases are quite significant, indicating that even without absolute control of stripe it is possible substantially to increase the yield on badly infected seed.

TABLE 4.—*Barley stripe seed-treatment test with plots one-half square rod in size, repeated three times, Nanking, China, 1926–27*

Treatment	Av. No. heads per plot	Per cent stripe	Yield bu. per A.		Gain in yield	
			Treated	Untreated	Bu.	Per cent
Copper carbonate	1387	5.5	54.0	44.0	10.0	22.7
Tillantin-Trochenbeize	1458	4.0	53.5	46.0	7.5	16.3
Uspulun-Dry	1401	4.0	55.6	46.0	9.6	20.9
Tillantin "B"	1387	4.0	52.3	42.3	10.0	23.6
Checks, av. of all	1382	10.8		44.6		

SUMMARY

Hulless barley, in two separate seed lots, each infested with *Ustilago hordei* and *Helminthosporium gramineum*, respectively, were treated with dry and liquid disinfectants.

Copper carbonate and dry Uspulun reduced covered smut to an average of less than one-half per cent. The copper carbonate had a different effect from that reported on hull varieties where no control was secured. No other treatments gave such consistently effective results as the two dusts mentioned above.

An average of two tests with stripe-infested seed gave 12.8 per cent stripe on untreated seed and 2.1 per cent on seed treated with dry Uspulun. In one test, copper carbonate reduced the percentage of stripe from 10.8 per cent on the checks to 5.5 per cent on the treated rows. This dust seemed less effective than liquid treatments, but it caused a high increase in yield. Soaking the seed in Uspulun solution for either one or two hours completely eliminated stripe.

The most important thing brought out in these tests is the yield response of hulless barley to some of the dust treatments. In the case of covered-smut control where yields were secured, the highest percentage of smut on untreated seed was 5.9 per cent (Table 1). In the latter case, the largest increase in yield due to treatment was 26 per cent. In another instance, shown also in table 1, where the smut infection in plots sown to untreated seed was only 2.76 per cent, the largest increase in yield was 27.2 per cent and the lowest was 11 per cent.

In table 3 the average percentage of stripe on untreated seed was 14.4 but the largest increase in yield where odds were significant was 23.9 per cent. The average increase for the three best treatments was 21.6 per cent. In table 4, the average reduction in stripe with four treatments was 6.4 per cent, while the average increase in yield was 23.4 per cent.

The increases in yield of hulless barley due to seed treatment were apparently greater than could be accounted for by the reduction of either of the two seed-borne diseases in question.

Seed treatment of hulless barley in the lower Yangtse river valley in China should become an important agricultural practice. Either dry Uspulun or copper carbonate may be used with success.

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A LEAF SPOT OF SYCAMORE CAUSED BY *STIGMINA PLATANI* (FUCKEL) SACC.[1]

C. A. APOSTOLIDES

In the fall of 1926 some diseased leaves of *Platanus racemosa* Nutt., attacked by some unknown fungus, were sent by the Rust Nursery, Pasadena, California, to the Plant Pathology laboratory of the University of California for diagnosis.

A leaf-spot disease has been known to occur in California on the leaves of *Platanus orientalis* L. (2), but to our knowledge has never been reported on the native California Sycamore, *Platanus racemosa*. The object of this investigation was the isolation and study of the causative organism of this leaf spot of *Platanus racemosa* and the determination of its relation to the fungus attacking the oriental Sycamore, *Platanus orientalis*.

In reviewing the literature of the disease of the Platanaceae the writer found that a leaf spot was reported by von Thümen (2) in 1871 and Saccardo (3), (4) in 1878 and 1880.

The symptoms of the disease under investigation are as follows: Scattered spots 1 to 3 mm. in diameter are found on the lower surface of the leaves. (Fig. 1, B.) When severely infected, the entire lower surface is black (Fig. 1, A), and the upper side shows extensive brown areas. When the leaves are not so heavily infected, a discoloration ranging from light to dark brown appears on both sides.

The disease is characterized also by a loosening of the epidermis from the affected areas. Directly beneath such areas are found the superficial bodies of the pathogene (Fig. 2).

The surface of diseased leaves was disinfected by placing them in a 1 to 1,000 solution of $HgCl_2$ for one minute. They were then removed, passed through several changes of sterile distilled water, and allowed to remain in each for five minutes. After surface disinfection, the diseased tissues were placed in a test-tube containing 2 cc. of sterile distilled water and crushed into small bits with a sterile metal rod. Thus a suspension of spores was made containing only one to two spores per loopful. Transfers were made from the last dilution to thin, clear agar plates and examined under the microscope.

[1] Submitted as partial fulfilment of the requirements for the degree of Master of Science, University of California.

The writer wishes to acknowledge his indebtedness to Professor W. T. Horne, under whose direction the work was conducted, for valuable suggestions and criticisms, and to Dr. T. E. Raulins for suggestions, criticisms, and encouragement.

FIG. 1. *A* shows the underside of a lightly infected leaf of *Platanus racemosa*. *B* shows the underside of a severely infected leaf of *Platanus racemosa*.

FIG. 2. Photomicrograph of a cross-section of a leaf showing distinctly an emergence of conidiophores and their conidia. (The leaves were imbedded in paraffin and the sections stained with Flemming's triple stain.)

After the fungus was obtained in pure culture, it was noted that on artificial media the organism grew very slowly and rarely produced spores. The following solid media were employed: Cornmeal agar, nutrient Czapek agar, plain agar (made by adding 20 grams of agar to 1,000 cc. of water), prune, potato, *Platanus racemosa*—leaf-decoction agar, potato plugs, carrots, rhubarb, and stems of white clover and California Sycamore, *Platanus racemosa*, bran corn, and steamed rice in 200 cc. Erlenmeyer flasks. These media were made according to Duggar (1, pp. 9–40). All carbohydrate media were sterilized for 30 minutes in autoclave at 7 to 10 pounds pressure. The fungus was grown in each medium at six different times. Detailed observations were recorded daily. Of all the media tried, Czapek's synthetic agar gave the best results. On this medium the fungus grew well and produced few spores. Czapek's agar was prepared as follows: Magnesium sulphate ($MgSO_4$) 0.5 gm., potassium chloride (KCl) 0.5 gm., monobasic potassium sulphate (KH_2PO_4) 1.0 gm., sodium nitrate ($NaNO_3$) 2.0 gms., iron sulphate ($FeSO_4$) 0.01 gm., sucrose 30.00 gms. in 1,000 cc. distilled water.

Diseased leaves of *Platanus racemosa* from Pasadena were imbedded in paraffin, sectioned, and stained with Flemming's triple stain. The slides disclosed an abundant growth of intracellular mycelium in the discolored portions of the leaves and tufted conidiophores (Fig. 2), with conspicuous

one- to three-septate, ovoid to elongate, olive green, terminal conidia, 15.0 μ long × 8.9 μ wide.

In order to determine the pathogenicity of the organism the following experiments were carried out.

Surface Inoculations: Spores and mycelium were applied with a brush to the lower surface of the leaves. To prevent drying, the twig bearing the inoculated leaves was covered with a wax-paper bag containing some moist cotton.

Puncture Inoculations: The second experiment was similar to the first, except for the injury caused by pricking the leaves with a scalpel. After inoculation, the leaves were covered with mason jars containing moist cotton and wrapped with dark paper. Checks, similarly prepared, accompanied the inoculation experiments, but with the fungus omitted. Infection resulted from both of these methods, as shown in table 1.

TABLE 1.—*Infection results obtained from inoculations of leaves of Platanus racemosa with Stigmina platani*

Date of inoculation	Trees inoculated	Method of inoculation	Date of first symptoms	Inoculated			Control	
				Number of leaves inoculated	Number of leaves infected	Per cent infection	Number of control leaves	Number of leaves infected
March 17, 1927	Tree No. 1	puncture	April 21, 1927	15	6	40.0	3	None
April 27, 1927	Tree No. 1	surface	June 18, 1927	19	9	47.3	3	do
June 2, 1927	Tree No. 1	surface	June 23, 1927	10	9	90.0	3	do
March 17, 1927	Tree No. 2	puncture	April 21, 1927	18	4	22.2	3	do
April 27, 1927	Tree No. 2	surface	June 18, 1927	15	3	20.0	3	do
June 2, 1927	Tree No. 2	surface	June 23, 1927	10	10	100.0	3	do
Total				87	41	47.1	18	None

The symptoms obtained from artificial inoculations were identical with those found under field conditions. The highest percentage of infection was obtained in June. This may have been due to the exceptionally warm

weather of that month. The inoculations made on March 17, 1927, resulted in distinct dark spots within five weeks, while inoculations made on April 27 and June 2, 1927, gave similar spots in three weeks. The inoculation experiments conducted in the greenhouse and in the open gave similar results, and the organism was identified as *Stigmina platani* (Fckl.) Sacc. (*Stigmella platani* (Fckl.). The fungus was twice reisolated from artificially infected leaves.

Influence of light on growth and sporulation of the fungus: In order to determine whether light influenced the growth of the fungus, cultures were kept a month in test-tubes of different media in the dark at room temperature. At the end of this time, they were examined and compared with cultures kept at room temperature but in diffuse light. No appreciable difference was noted in the growth of the organism on any of the media used. Thus it appears that diffuse light has little if any influence on the growth of the fungus.

SUMMARY

Studies were made of a leaf spot of the native California Sycamore, *Platanus racemosa*.

A fungus was isolated, the disease was produced by inoculating leaves with the isolated organism, and the fungus was reisolated from the artificially infected leaves.

Czapek's agar was found to be the most favorable medium for the growth and sporulation of the fungus.

Studies of the morphology of the organism show it to be *Stigmina platani* (Fckl.) Sacc. (*Stigmella platani* Fckl.), an organism which causes a leaf-spot disease of *Platanus orientalis*.

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THE LIFE HISTORY OF SPHACELOMA AMPELINUM DE BARY[1]

C. L. Shear

The fungus, commonly known as *Sphaceloma ampelinum*, is the cause of a serious grape disease in the eastern United States and also in Europe. The disease, usually called anthracnose, sometimes causes heavy losses to both vinifera and American grape varieties. It attacks foliage, fruit, and canes. The disease appears to be of European origin and has been known for many years. According to Viala, specimens collected in 1839 are preserved at Montpellier, and it is believed that a disease of the vine mentioned by Theophrastus and Pliny is anthracnose. De Bary (3), in 1873, investigated the disease and gave an accurate description of the conidial form of the fungus, naming it *Sphaceloma ampelinum*. The earliest report of its appearance in this country, so far as we know, is that by the late Professor Burrill (7), of Illinois, who says he found it in that state in 1881. Since that time the disease has been the subject of numerous studies by different investigators in this country and Europe. As a result, the fungus has received several different names. Comes (8, p. 425) gives as synonyms *Torula meyeni* Ber. & Trev. and *Ramularia meyeni* Gar. & Catt. According to Saccardo, Passerini named it *Ramularia ampelophaga*. A little later Saccardo transferred it to the genus Gloeosporium. In 1904 and 1905, Viala and Pacottet (14, 15), in an elaborate series of papers on diseases of the vine gave an account of their cultural studies of the organism. According to their investigations the organism is extremely pleomorphic as well as polymorphic, producing two or three conidial stages; a yeast form with an ascospore stage, giant cells, resting spores, and mono- and polysporous cysts, as well as pycnidia and spermagonia. As a result of their studies they concluded that the organism should have a new generic name and they rechristened it *Manginia ampelina*, V. & P., referring it provisionally to the Sphaeropsideae and stating that when the perithecial form was found it could be put in its proper place among the Pyrenomycetes.

The writer has studied this organism in the field and in culture for many years, but has never been able to obtain in pure cultures all the forms described by Viala and Pacottet. The conidia bud readily in culture, producing forms resembling those which they describe and figure as yeast. We also find in the mycelium bodies corresponding to their cysts (Fig. 1). These are very variable in form, size, color, and septation and sometimes have the appearance of containing spores. We have never found the other

[1] Presented before Botanical Society of America, Mycological Section, December 28, 1928.

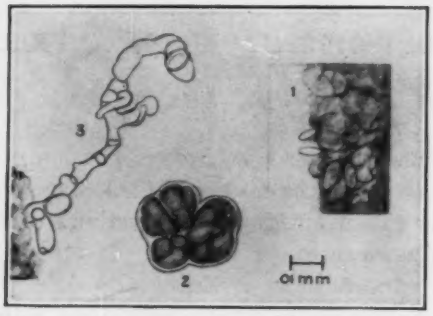

FIG. 1. *Elsinoe ampelina.* 1. Mass of cyst-like bodies bearing conidia. 2. Mature cysts with contents divided. 3. Cyst-like bodies in early stage of formation. All from pulp of an old grape destroyed by anthracnose.

forms of conidia which they figure nor the pycnidia and spermagonia which they describe and illustrate. We have, however, obtained in cultures made by transplanting diseased tissue of anthracnose spots on grapes pycnidia of a Phoma corresponding to the pycnidia which they describe. All such cultures, however, were shown to be impure when single conidia of the anthracnose fungus were isolated and grown separately. As a result of a study of closely related organisms such as *Gloeosporium venetum* Sacc. and the citrus scab organism we are led to suspect that their cultures were impure.

Early in our work on small fruit diseases we noted the striking similarity between cultures of *Gloeosporium venetum* Sacc., the fungus causing anthracnose of raspberries and blackberries, and those of the grape anthracnose fungus. In fact, the similarity is so close as to suggest the specific identity of the organisms.

In 1914 Burkholder (4) published an abstract and in 1917 (5, 6) the complete results of his studies of *Gloeosporium venetum* in which he showed that it is the conidial form of an ascomycete which he referred to the genus Plectodiscella of Woronichin (16). It at once occurred to us that the grape anthracnose fungus probably had a similar perfect stage, and this probability was suggested in a paper on grape anthracnose presented by the writer (13) at the International Congress of Viticulture in San Francisco in 1915. A few years later a serious outbreak of anthracnose in a vineyard near Norfolk, Va., came to our attention and provided an opportunity to secure an abundance of fresh material. Failing in all of our efforts to obtain the perfect stage of the fungus in culture, a quantity of severely cankered canes and shoots was obtained and kept out of doors over winter at Washington. In the spring a careful examination of these old cankers showed ascocarps very closely resembling those described and

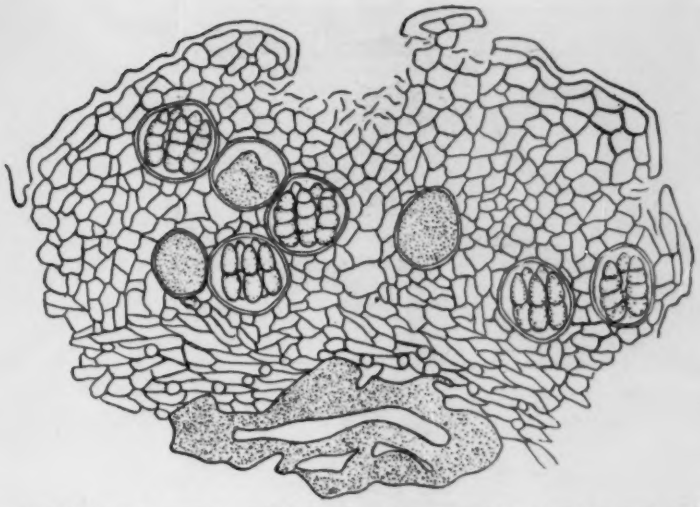

FIG. 2. *Plectodiscella veneta.* Section through an ascocarp, showing asci and ascospores × 850 (after Burkholder).

illustrated by Burkholder for *Plectodiscella veneta.* (Fig. 2.) Later some of these ascocarps showed nearly mature asci and ascospores. The ascospores are hyaline, 3-septate, and 15–16 x 4–4.5 μ; perhaps somewhat larger when fully mature. (Fig. 3.) Unfortunately, we were unable to get single ascospore cultures from this material, either because the spores were immature or the cultural conditions unfavorable. The evidence therefore of the genetic relation between *Sphaceloma ampelinum* and the ascocarps found in the cankers is at present circumstantial, being based upon the close association of the two forms in the cankers and the sequence of development and also the fact of the very close similarity between the Rubus anthracnose organism in both its stages and the grape anthracnose fungus. In fact, it is difficult to separate the two organisms on very satisfactory cultural or morphological characters in either the conidial or ascogenous stage. They are, however, at least physiologically distinct, as Dr. Anna E. Jenkins, of the Office of Mycology and Disease Survey, has shown by careful inoculation experiments (unpublished) that the raspberry anthracnose fungus will not infect the grape.

This fungus belongs to a very interesting group of ascomycetes apparently to be included in the order Myriangiales. It is characterized by ascocarps consisting of mostly pseudoparenchymous tissue in which the asci are irregularly distributed and imbedded (Fig. 3).

The genus Plectodiscella described by Woronichin (16) in 1914 and based upon *P. pyri* Wor., which causes a leaf spot of apple and pear in

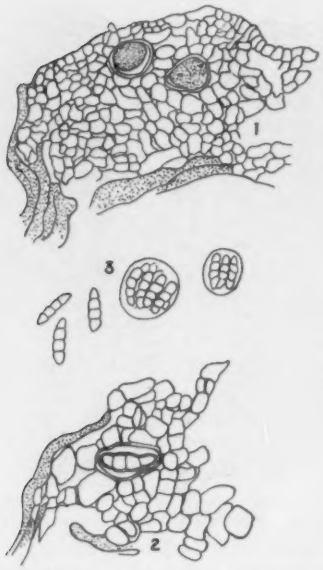

FIG. 3. *Elsinoe ampelina*. 1. Vertical section of an ascocarp with young asci. 2. Portion of an ascocarp with one ascus and nearly mature spore. 3. Asci and ascospores. From old anthracnose canker on grape shoot.

the Caucasus, has a very similar ascocarp, but more regular in outline and with a rather definite dark colored outer covering (Fig. 4), whereas the anthracnose fungus apparently has no distinct superficial layer. Arnaud (1), 1925, in discussing this and closely related genera, adopts the generic name Uleomyces of Hennings and gives as synonyms thirteen generic names, including Plectodiscella. The type of Uleomyces, *U. parasiticus* P. Henn., would hardly be regarded by most mycologists as congeneric with the type of Plectodiscella. *Uleomyces parasiticus* P. Henn. (*U. sanguineus* (Speg.) v.H.) as shown by Arnaud's (1) description and figures has a superficial stroma and many septate, muriform, brown ascospores, instead of hyaline 3-septate spores, as in the type of Plectodiscella. One of the genera which Arnaud regards as a synonym of Uleomyces is Elsinoe of Raciborski (11). The type of this genus is *E. canavalliae* Rac. 1900 (Fig. 5). From Arnaud's detailed description and illustrations of the type collection of this species, it is very clear that Elsinoe is a synonym of Plectodiscella, unless the dark colored superficial cover in the latter be considered a distinctive character, and that the type species of Elsinoe is very similar in all of its characters to *P. veneta* on Rubus and to the species on grape. On the basis of priority therefore the generic name of the apple, Rubus, and grape fungus should be Elsinoe, Raciborski, 1900, instead of Plectodiscella, Woronichin, 1914. We would therefore refer the ascogenous

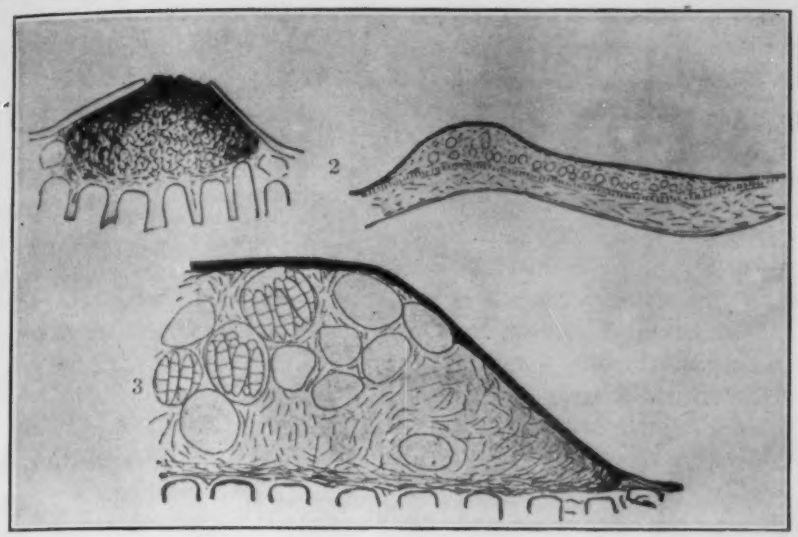

FIG. 4. *Plectodiscella pyri*. 1. Section through fundament of a stroma. 2. Young stroma. 3. Section through a mature ascocarp. (1, 3×500; 2×82; after Woronichin.)

form of the grape anthracnose organism to the genus Elsinoe as *E. ampelina* n. sp. In this connection it should be mentioned that Raciborski (12) described a species of Elsinoe which he collected in Java as *E. viticola*. It was found on leaves of a species of Vitis. His description of the asci and spores agrees very closely with our grape fungus, and it is possible as Jenkins and Horsfall (10) suggest that *E. viticola* Rac. is a synonym of *E. ampelina* (de By.) Shear, **n. comb.** Arnaud, however, states that he was unable to find any good ascocarps of *E. viticola* on the specimens from Raciborski preserved in the Paris Museum.

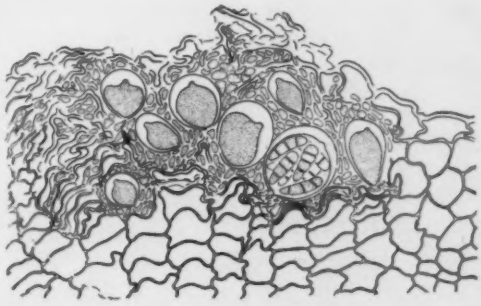

FIG. 5. *Elsinoe canavallae* Rac. Section of an ascocarp showing asci and ascospores (after Arnaud).

It is interesting to note in connection with the life history of these organisms the remark made by Arnaud (1) in his reference to *Plectodiscella veneta* Burk., p. 688. In speaking of the genetic relation between *Gloeosporium venetum* and Plectodiscella, as shown by Burkholder, he says, it is more probable that the Plectodiscella is a parasite of the Gloeosporium. This remark was apparently suggested by the fact that most of the species of this group appear to be parasites on other fungi, rather than by a careful consideration of the very convincing evidence produced by Burkholder.

Doctor Jenkins (9, 10) has shown that the citrus scab organism is a Sphaceloma and that there is also one on Avocado and rose. She has also found on the type specimens from Woronichin conidia of Sphaceloma which were not mentioned by him in his description of *Plectodiscella pyri.*

Our present knowledge of the ascogenous stages of conidial forms of Gloeosporium furnishes an excellent example of the great diversity of ascogenous forms having similar conidial stages, *e.g., Pyrenopeziza ribis,* conidia, *Gloeosporium ribis; Glomerella cingulatum,* conidia, *Gloeosporium cingulatum; Plectodiscella venetum,* conidia, *Gloeosporium venetum.* On the other hand we have such cases as Physalospora and Botryosphaeria with very similar ascocarps but with such different pycnidial forms as Sphaeropsis and Dothiorella as their respective imperfect stages.

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THE EFFECT OF *TILLETIA CARIES* (DC.) TUL. (*T. TRITICI* (BJERK.) WINT.) ON THE DEVELOPMENT OF THE WHEAT EAR

W. A. R. Dillon Weston, M.A.

In the course of investigations carried out at Cambridge during the past six years on the relative resistance and susceptibility of wheat varieties to bunt, the writer has made observations on the morphological changes which take place in infected ears of a large number of wheat varieties.

Figure 1 is the variety American Club (*T. compactum* Host.). The ear on the left is bunted, and the one on the right is clean. It will be seen that

Fig. 1 is the variety American Club (*T. compactum*). The ear on the left is bunted, the ear on the right is clean.

some of the spikelets on the bunted ear are awnless. En passant it is interesting to note the elongation of the ear in this case. This, although not invariably occurring in *vulgare* types, is very general; in *compactum* types, however, in our own experiments with winter-sown American Club it has invariably occurred, and the bunted *compactum* head is then very similar to a clean *vulgare* variety. Appel (1, 2) and Edler (3) have

previously discussed this extreme difference and it appears that exceptions occur more frequently in spring-sown club. Such marked elongation has not been noted in other species which have been under observation:—viz, *T. sphaerococcum* Perc., *T. Spelta* L., *T. polonicum* L., *T. durum* Desf., *T. dicoccum* Schr., *T. persicum* Vav. and *T. turgidum* L.

Figure 2 shows the variety Velvet Don (*T. durum*). The bunted ear is on the left and the clean is on the right. There is again a total suppression of awns.

FIG. 2 is the variety Velvet Don (*T. durum*). The ear on the left is bunted, the one on the right is clean.

Figure 3 shows the variety Turkey (*T. vulgare*). The bunted ear is on the left and the clean, on the right. In this case also there is a total suppression of awns.

Figure 4 is the same variety. Three ears on the left have awns and three ears on the right are awnless, but the specimens on both the right and left are bunted.

The following explanation of this phenomenon is offered. The ears on the left were harvested two or three weeks before those on the right. In the first case they were cut when immature and still green, but in the second case they were cut when ripe. This "suppression" of awns is therefore clear. It has no genetical significance, and is due to the awns break-

FIG. 3 is the variety Turkey (*T. vulgare*). The ear on the left is bunted, the one on the right is clean.

FIG. 4 is the variety Velvet Don, awned and awnless. Each specimen is bunted, but the awned specimens were harvested before they were ripe.

ing off when the culms swayed from side to side. It may be argued that in these cases why did the awns of healthy ears not break off? It is suggested that parasitism of this nature will inevitably result in a weakness in the host; for example, infection with bunt in the majority of cases increases the susceptibility of a variety to yellow rust (4) (6). Moreover, the life history of the host will be prematurely terminated since, in consequence of the complete parasitism, the last remaining sources of food will be required to nourish the parasite in the production of its countless progeny.

Figure 5 is the variety Marshal Foch (*T. vulgare* Vill.). The plate shows two ears, the one on the left is bunted, the one on the right is clean. In the case of this variety where the normal awns exhibit a small development only it will be noted that the awns in the bunted ear are not suppressed.

Murashkinski (5) in a recent paper discusses these modifications and draws attention to the suppression of awns in normally awned varieties. The purpose of this note is to show the true nature of this suppression.

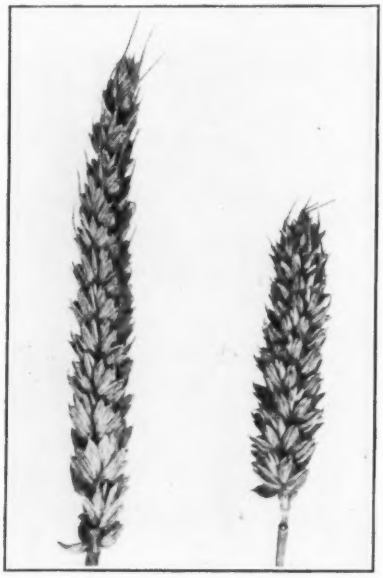

FIG. 5 is the variety Marshal Foch (*T. vulgare*). The ear on the left is bunted, the one on the right is clean.

The writer is indebted to Mr. C. W. Williamson for the photographs of these wheats.

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CAMBRIDGE, ENGLAND.

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PHYTOPATHOLOGICAL NOTES

Report of the Cotton Root-Rot Conference at College Station, Texas.—The root-rot disease, caused by *Phymatotrichum omnivorum* (Shear) Duggar (*Ozonium omnivorum* Shear), is one of the most destructive plant diseases known and is of tremendous importance in the agriculture of the Southwest. In 1927, a much expanded program of investigation at the Texas Agricultural Experiment Station was made possible through special appropriation of $100,000 by the legislature for basic research on root-rot during the following biennium. This work has been carried on at College Station and at the Temple, Iowa Park, and Weslaco substations. More recently, Congress has also made special appropriations for work on root-rot, to be carried on by the Bureau of Chemistry and Soils with headquarters at Austin, and the Bureau of Plant Industry with headquarters at Greenville. These various research agencies have recently entered into a cooperative agreement for the purpose of obtaining maximum results in the study of the cotton root-rot problem with the facilities available.

The purpose of the conference, called by Director A. B. Conner of the Texas Agricultural Experiment Station and held at College Station on January 14 and 15, 1929, was to bring together the workers with root-rot from these various organizations, determine the present status of knowledge, and plan for future investigation. Dr. J. J. Taubenhaus, Chief of the Division of Plant Pathology and Physiology, and in charge of the root-rot research of the Texas Experiment Station, presided. The scope of the discussions of results obtained in the various studies of root-rot may be indicated from the headings of the program: Description, distribution, and importance; the fungus; infection and wintering-over problems; environmental relations; control; discussion of future work.

Some significant results presented at the meeting by the Texas Experiment Station workers were as follows: *Phymatotrichum omnivorum* is greatly inhibited in growth at pH 6.0 whether this acidity is produced by any of three different acids.[1] In an extensive survey, root-rot was found in only 34 per cent of fields with even slightly acid soils and in 71 per cent of fields with alkaline soils and was not destructive even when present in acid soil. Seven different soils were used in an experiment in which each soil was placed in a long box, a row of cotton planted along the middle, and one end of this row inoculated. Spread of root-rot correlated directly with the pH of the soil, and infection did not occur in the two more acid soils.

[1] A portion of these results is given in: Taubenhaus, J. J., W. N. Ezekiel, and D. T. Killough. Relation of cotton root rot and Fusarium wilt to the acidity and alkalinity of the soil. Texas Agr. Exp. Sta. Bul. 389. 1928.

In three additional series of experiments at College Station during 1928, the incidence of root-rot, its spread, and the number of plants killed, were again found to be influenced by the acidity of the soil. In artificial inoculations in a long field plot, nearly perfect results were secured along the greater length of the rows, while at one end most of the plants remained normal. Again, the soil was found to be more acid where the plants remained uninfected. From these different lines of work, it was concluded that the reaction of the soil has a marked influence on root-rot and that this disease may perhaps be controlled by changing the soils to the proper acidity.

Preliminary experiments with soil acidity as a control measure were reported. Eight commercial sulphur materials were tested in containers at College Station. Plants killed by root-rot were reduced from 40 per cent in the checks to 3 per cent, 1 per cent, and 0, with the addition of large amounts of sulphur. In preliminary field tests during the season of 1928, the addition of sulphur was found of little value in soils that contained large amounts of lime; while with soils that were only slightly alkaline or neutral there was marked reduction of loss. Cotton is very susceptible to sulphur injury which occurred both in field and container experiments when heavy applications were made. It was emphasized in discussion that soil acidity as a control measure is still in the experimental stage, would have to be controlled very carefully to prevent injury to cotton, and would be applicable only to the portions of the Southwest where the soils are not so strongly alkaline as to make acidification prohibitive in cost. However, millions of acres of land in Texas were shown to be of types probably suited to this treatment.

Another line of approach was with regard to the factors underlying the rotation and clean-culture method of control, which remains the method to be recommended in the alkaline "black lands" where cotton root-rot is very destructive. Experiments were reported in which soil from the advancing edges of root-rot spots was sifted and placed in large containers. Root-rot did not attack cotton planted in this sifted soil, while in check containers of unsifted soil (which included the roots of plants) there was always root-rot. In fields, it was found that the diseased roots of the first plants, naturally infected in spring, could be traced back to roots in the ground that had over-wintered and were carrying root-rot. Numerous perennial weeds were found carrying root-rot over winter on their roots. In inoculation experiments with infected cotton roots, root-rot could not be transmitted by roots of plants that were dead; while high percentages of infection were obtained when living roots infected with root-rot were used as inoculum. These results support the tentative conclusion that root-rot lives over winter

chiefly on the living roots of susceptible plants and not in the soil itself; and suggest that, if perennial weed carriers are kept down by proper cultural methods, control may be secured with rotations that allow the roots of susceptible crop plants to die off before the next susceptible crop is planted. Studies on cotton roots have shown that many remain alive in the soil over winter and gradually die off during the following summer and fall. Similar studies are in progress with the roots of susceptible weeds.

Tests for varietal and individual resistance in cotton have been carried on at the Temple substation. During the past season, 5200 selections were included in the artificial inoculations and little resistance was found. Dr. R. B. Streets, however, stated that he had selected Pima and Acala strains which appeared to be resistant.

Dr. D. C. Neal, of the U. S. Department of Agriculture, reported that he had been able to confirm observations previously made by Messrs. C. J. King and H. F. Loomis, also of the U. S. Department of Agriculture, and had obtained true sclerotia of *Phymatotrichum omnivorum* in artificial culture, in addition to the pseudosclerotia previously known. Dr. Taubenhaus described the production of a spore mat (the Phymatotrichum stage) in a box containing plants artificially inoculated with root-rot.

Results of the work of the Bureau of Chemistry and Soils during the past season were presented by Dr. Oswald Schreiner and Dr. Paul R. Dawson. Preliminary fertilizer experiments yielded inconclusive results. Root-rot was found to occur only in the less acid part of a field in which it was distributed unevenly.—W. N. EZEKIEL, College Station, Texas.

Leptosphaeria foot-rot of wheat in Alberta.—In addition to *Helminthosporium sativum* P. K. and B., *Ophiobolus graminis* Sacc. and *Fusarium* spp., all of which cause foot-rots of wheat in Alberta, another organism has been isolated from wheat plants affected with foot-rot. It was first obtained from wheat stubble collected at the University of Alberta in October, 1927. In has since been obtained from various parts of the Province. Perithecia of this fungus have been found in abundance on old wheat stubble. In one case numerous perithecia were found on wheat stubble of the first crop after breaking and a similar fungus was collected on wild grasses surrounding the field.

The fungus proved to be a species of Leptosphaeria, the ascospores of which closely resemble those of *Leptosphaeria herpotrichoides* de Not., one of the most important cereal foot-rotting fungi of continental Europe. The ascospores measure 25–40 μ (33 ± 2) x 4–6 μ and are 6 to 8-septate. In the specimens so far examined, however, the ostioles are less raised and the perithecia lack the hairiness described for *L. herpotrichoides*. In the latter

respect our fungus more nearly resembles *L. culmifraga* Fries (Ces. and de Not.), which, according to Saccardo,[1] scarcely differs from *L. herpotrichoides* except in its less villose perithecia. According to Mangin[2] these characters of the perithecia vary widely in different collections of *L. herpotrichoides*. Their development is probably greatly influenced by environmental factors. Another characteristic in which our fungus corresponds to *L. herpotrichoides* is in the production of "ampoules perforatrices" or appressoria described by Mangin,[2] Foëx,[3] and others as typical of this species. These were produced abundantly on Marquis wheat artificially inoculated with a monosporous culture.

The fungus did not cause seedling blight like *Helminthosporium sativum* and *Fusarium graminearum* Schwabe, but attacked the plants later, in this respect resembling *Ophiobolus graminis*. Definite foot-rot symptoms were produced in laboratory and greenhouse tests. The optimum temperature for vegetative growth apparently lies between 20 and 25° C., thus corresponding more closely with *Ophiobolus graminis* than with the other above-mentioned foot-rotting fungi. Specimens submitted to the Imperial Bureau of Mycology were kindly compared with herbarium material by E. W. Mason, to whom we are indebted for an excellent report.—A. W. HENRY and W. R. FOSTER, University of Alberta, Edmonton, Canada.

A fruit spot of tomato caused by Aplanobacter michiganense.—A very characteristic fruit spot of tomato, found in Georgia in 1928 and 1929 and in Mississippi in 1929, in fields where bacterial canker was present, has been definitely proved to be another phase of this disease caused by *Aplanobacter michiganese* E. F. Sm.

The spots are unlike those produced by *Bacterium vesicatorium* Doidge. They are round, never dendritic; are white, at first; later, have a lenticular rift or round, light brown, roughened center surrounded by a white halo; are never water-soaked; and may fuse to form large, roughened patches. In late stages they are dark brown but, even then, often retain the white halo.

Aplanobacter michiganense has been isolated repeatedly from natural infections, used to produce fruit spots like those from which they were isolated and reisolated from these spots. Also typical systemic infection has been produced with fruit-spot isolations and fruit-spot with isolations from typical systemic lesions.—MARY K. BRYAN, Bureau of Plant Industry, U. S. Department of Agriculture, Washington, D. C.

[1] Saccardo, P. A. Sylloge Fungorum. Vol. 2. Patavii. 1883.

[2] Mangin, L. Sur le piétin ou maladie du pied du blé. Bul. Soc. Mycol. France **15**: 210–239. 1899.

[3] Foëx, E. Observations sur le piétin du blé. Ann. Serv. Épiphyties **6**: 200–213. 1919.